BIOLOGY

A Textbook for Higher Secondary Schools

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Distributed by :
Chief Publication Officer,
Publication Unit,
National Council of Educational Research and Training,
114-Sunder Nagar, New Delhi.

January 1965–10,000

Price : Rs. 2.75 or 6sh. 5d. or 99 cents.

Printed at the National Printing Works, 10, Daryaganj, Delhi.

BIOLOGY

A Textbook for Higher Secondary Schools

SECTION 2

The Diversity of Plant Life

Edited by
P. MAHESHWARI
and
MANOHAR LAL

National Council of Educational Research and Training

ACKNOWLEDGEMENT

The National Council of Educational Research and Training has undertaken a major programme to prepare model textbooks in different subjects for the school curriculum. For this purpose, the Council has set up a Central Committee for Educational Literature to guide and direct the programme Panels of specialists have been set up by the Central Committee to develop curricula and to write text-books, teachers' resource books and other materials on school subjects

The Biology Textbook Panel under the Chairmanship of Prof P. Maheshwari, Head of the Department of Botany, Delhi University, has been developing for the last two years, curriculum, syllabus and textbook of biology for higher secondary classes

The biology curriculum and text material were reviewed by practising teachers and science educators before they were finalised. Section 1 of the textbook was published in September, 1964 and since then, it has been adopted by the higher secondary schools affiliated to the Central Board of Secondary Education. The present publication deals with Section 2 of the series devoted to 'The Diversity of Plant Life'.

The National Council wishes to thank Prof. P. Maheshwari, the Chairman, and members of the Biology Panel for their valuable contribution to the preparation of the biology books

The remaining five sections of the textbook will be published in the course of 1965. It is also proposed to publish one single volume containing all sections together

The National Council invites suggestions from teachers and science educators on the biology series.

L.S CHANDRAKANT
Joint Director
National Council of Educational

New Delhi,
January 15 1965

Foreword

FOR several years I have seriously felt the lack of good school and college textbooks on biology. Most of the existing books emphasize only the descriptive aspects of the subject, largely ignoring the newer and more fundamental concepts This is, in part at least, responsible for adversely influencing the public image of biology and for relegating it to a subordinate position in the list of sciences No thinking person can doubt that biology profoundly affects the life of all human beings and its study is one of the most essential requisites of every responsible and intelligent citizen Further, the study of biology must begin right in the school as an integral part of any course in science instead of being postponed to the college or university stage The pupil's choice of the subject of his future study is determined, to a large extent, by the courses he has attended in school and by the type of text matter presented to him at this stage.

Recognizing the above facts, I readily accepted the invitation of the National Council of Educational Research and Training to act as Chairman of the Panel set up to prepare a new and modern textbook suited for use in Indian Secondary Schools

This pamphlet is the second section of the textbook It deals with 'The Diversity of Plant Life' spread over 14 chapters The subsequent sections will be brought out in due course and when they are all ready the book will also be produced as a single bound unit.

It may be noted that there are several ways of approaching the subject of biology, each having its own merits and demerits The editors and members of the Panel are convinced that a wide acquaintance with a number of different kinds of organisms, their activities, their habits and their tissues and organs, is essential and basic to the understanding of the general concepts of evolution, ecology, heredity, and cell physiology. This approach, in their opinion, combines not only the pedagogical advantage of proceeding from the known to the unknown but also prevents students from getting lost in the intricacies of the more advanced aspects of biology.

Although evolution is treated separately in two chapters, an attempt has nevertheless been made to acquaint the student with this all pervasive principle during his study of the world of life. Biological phenomena common to plants and animals have been discussed together as far as possible Technical terms have been kept down to the minimum except when their use is believed to contribute to easier communication and understanding Important biological discoveries have been dealt with in a historical perspective to give an idea of how science progresses.

It has been our objective to present the subject in an understandable, stimulating and instructive fashion. We shall appreciate receiving comments, criticisms and suggestions These will be taken into account in bringing out a revised version of the book

The original drafts of the chapters in the book were contributed by several persons whose names are given below in alphabetical order: Dr. R.N Chopra, Reader in Botany, University of Delhi, Mrs. E. Gonzalves, Biology Department, St. Xavier's College, Bombay, Prof N B Inamdar, Head of the Department of Zoology, Institute of Science, Bombay, Prof B M Johri, Department of Botany, University of Delhi, Dr. G N Johri, Head of the Department of Zoology, Shia College, Lucknow, Dr. L N. Johri, Reader in Zoology, University of Delhi; Dr. M S. Kanungo, Reader in Zoology, Banaras Hindu University, Dr. Manohar Lal, Department of Botany, University of Delhi, Dr S C Maheshwari, Reader in Botany, University of Delhi; Dr. L P Mall, Reader in Botany, Vikram University, Ujjain; Prof R D. Misra, Head of the Department of Botany, Banaras Hindu University, Prof M R N Prasad, Department of Zoology, University of Delhi; Dr H Y Mohan Ram, Reader in Botany, University of Delhi; Dr B. Tiagi, Reader in Botany, University of Rajasthan, Jaipur; and Dr H.S Vishnoi, Department of Zoology, University of Delhi.

There was naturally a good deal of editing work to be done in order to bring the manuscripts into a form suitable for publication, and to add the illustrations to make the text understandable In this I was ably assisted by my colleague Dr. Manohar Lal whose help was invaluable in looking after the large volume of work associated with such a project

I was receiving the ungrudging help of several other persons among whom special mention must be made of Mr. G S Paliwal, Dr. Sipra Guha and Mr Man Mohan Johri of the Botany Department, Delhi University, who looked after much of the day to day routine and the reading of the proofs. Prof Ralph Buchsbaum of the Department of Zoology, University of Pittsburgh, critically read through Section 3 on animals, Prof. W.N. Stewart of the Department of Botany, University of Illinois, gave many useful comments on Section 2 dealing with plants; and Dr S C. Maheshwari of the Department of Botany, University of Delhi, read Section 4 on

physiology Two school teachers—Mr S M Sharma of the Harcourt Butler Higher Secondary School, and Miss Katherine Bolton of St. Thomas Girls' Higher Secondary School—went through some of the chapters and offered several helpful suggestions The help received in the form of photographs and other copyright material is acknowledged in the captions

I must add that the book might never have seen the light of the day but for the constant help and generous cooperation of the following officers of the National Council of Educational Research and Training · Shri Raja Roy Singh, Joint Director, Shri P N Natu, Secretary, Dr R.N Rai, Head of the Department of Science Education, Mrs. S. Doraiswami, Chief Publication Officer; and Mr S Doraiswami, Secretary of the Biology Panel

Delhi
September 1, 1964

P MAHESHWARI
Chairman, Biology Panel,
National Council of Educational Research and Training

Preface

IN the midst of the present remarkable achievements in rocketry, nuclear energy, synthetic plastics and fibres, and exploration of space, the study of living organisms, their functions and their importance is frequently minimized or overlooked It is often forgotten that the primary aim of science, apart from the satisfaction of intellectual curiosity, is the survival and welfare of man Nothing has contributed more to human welfare and to the very emergence of man from his early animal behaviour, than the knowledge of plants, animals, and his own body. It is said that there are four chief ravages of humanity—diseases, wars, famine, and now over-population. From man's point of view, therefore, biology is the most fundamental and important of all the sciences. It affects vital state policies on matters like conservation of natural and human resources, radiation experiments, population control, quarantine and health programmes Biology also helps us answer such personal questions as. what determines sex; who is responsible for the sex of the baby—the mother or the father; how are twins born, why do babies resemble their parents, how do we acquire immunity against a disease, why do we become enfeebled in old age; how are plants and animals interdependent, and so on. Sanitation, nutrition, pest control, and other attributes of intelligent citizenship—all require a biological background Finally, biology—a study of the unity as well as the diversity of plant and animal life—is an intellectually enlightening and aesthetically satisfying experience. Indeed, in view of its importance in everyday life, biology should be made a compulsory subject for all school boys and girls. For all this we need adequate textbooks which present the subject in a satisfactory manner keeping in view the needs of the country for which the book is written. The present book is an attempt in that direction.

Should Botany and Zoology be Taught as Separate Subjects? The book adopts, in so far as possible, a common treatment of plants and animals and attempts to emphasize the basic unity in the organization and functioning of living matter. This might appear at first sight to be rather undesirable to those who are used to teaching botany and zoology as separate, well-defined subjects with little or no similarity. They might indeed question

the commonness between a cow and a 'neem' tree To such critics we owe an explanation right in the beginning

In the 19th century there was a tendency towards compartmentalization of subjects but the insight into the life processes acquired in the past 50 years has shown how these compartments merge into each other Recent work on cell physiology with the newer techniques of biochemistry and biophysics has particularly called attention to a basic commonness between plants and animals This common ground also extends into the fields of genetics, cytology, evolution, physiology and electron microscopy There is no reason why at the higher secondary stage the student should not be apprised of these broadening horizons. So far as some other aspects are concerned, the book still retains separate sections on plants and animals It may be added that in English and American schools a composite biology course has been in use for the last 10 to 15 years and some universities too have recently begun to offer similar courses at the B Sc level.

Even at the research level, many well-known laboratories in the U K. and the U S A have a common unit for work on both plants and animals. If we are to train the younger generation for successful careers in biological research, it is necessary to orient our school courses in such a way that they get the right perspective of the subject It may also be pointed out that the school biology course would be the only one which many of our boys and girls will ever attend in their life.

Biology in the Twentieth Century. The 19th century biologists concerned themselves mainly with the morphology and anatomy of plants and animals. While this was natural, the subject has undergone much change in its content and character in the 20th century. This has been made possible largely by the availability of new techniques of chemistry and physics although many milestones have also been laid purely by keen observation and logical analysis The rediscovery of Mendel's laws of heredity infused new interest into the field of genetics and the mechanism of inheritance was firmly established Artificial means of inducing mutations in plants and animals were discovered and the genes responsible for the expression of a particular character were pin-pointed Electron microscopy, ultracentrifugation, spectrophotometry and other techniques have further unravelled the intricate machinery of the living cell and these studies have now gone as far as the isolation and artificial synthesis of the hereditary substance—DNA The study of enzymes, which was a minor discipline in the last century, has grown into a vast area of research. Our knowledge of vitamins, hormones and antibiotics is also a gift of the present century biology. An understanding of the mechanism of nerve action, brain functioning, photosynthesis, respiration and a host of other physiological processes is also derived from the researches of the last 40 years To this list may be added the still more recent disciplines like virology, radiation and space biology, the cure for cancer and heart diseases, and finally the attempts to synthesize life itself!

Thus, the emphasis has largely shifted from a descriptive and morphological treatment to the functional aspects It is apparent that if we continue to train our students only in 19th century biology, as indeed is being done in most of our schools and colleges, they will find themselves unsuited to the future needs of the scientific world

The Need For Change. One factor which makes the present courses rather dull is that their contents are mostly or entirely descriptive We think that the morphological part must still form the basis of biology and has to be done well but this cannot be the only part and that physiology, ecology, evolution, the interrelations between plants and animals, and the role of biology in human life are subjects that cannot be left out of consideration A large fund of biological information acquired during the present century finds no mention in most Indian texts, nor do they provide any information about the interdependence of plants and animals Indeed, many of the existing books are as much as 50 years behind current biological thought. It is perhaps true that some aspects of biology, involving a rather intensive knowledge of chemistry and physics, are too advanced and complicated to be understood by the school student However, recent tests on the learning potential of young students have clearly shown that the general principles of physiology and genetics can be effectively taught provided a simple and popular approach is adopted and there is some demonstration material for illustration. For instance, problems like—what happens in photosynthesis or respiration and how living organisms respond to external and internal stimuli—elicit greater interest in the minds of students than learning the characters of a family of plants or describing the pectoral girdle of frog Similarly, on the practical side, the young student will take much greater interest in experimenting on the digestion of starch by an enzyme than in sketching the shapes of leaves and bones. It would be appalling if a school student should get the impression that biology is nothing more than cutting up frogs and collecting hay, or just a system of naming plants and animals in unfamiliar language.

It is sometimes argued that our textbooks are already encyclopaedic and that it is hardly possible to add more material in view of the time at the disposal of the students. This no doubt poses some difficulty because scientific knowledge is doubling itself every 10 to 15 years. Indeed, the 20th century has provided far more scientific information than the last 5000 years. This knowledge must naturally be incorporated into broad biological concepts so as to become a part of our everyday thinking. To do this one has obviously to cut out certain other portions Such facts as are only of an additive nature or matters of unnecessary detail must therefore be pruned and the dead wood removed here and there. To take a specific instance, a student need not spend too much time in learning the variations in the organization of flowers or vertebrae. Since everything cannot be taught at the school stage, a judicial balance has to be struck between depth and breadth

Another surprising factor is that past courses in India in this subject have virtually excluded the study of human biology. While the students have been studying in detail the various types of roots and stems as well as the smallest bones of a frog, they remained wholly ignorant of their own body.

The Book. The book has been divided into seven, more or less independent, sections. In the first section the student is introduced to the subject matter of science, particularly biology, and the characteristics of the living matter A glimpse of the variety of plant and animal life prepares the student for a more detailed study of these forms in the second and third sections The fourth section treats the main physiological processes in animals and plants in a simple way. The fifth is devoted to a comparative account of the different modes of reproduction in the plant and animal kingdoms. Heredity, evolution and ecology form the sixth section of the book The epilogue to the book covers topics like human diseases, interdependence of plants and animals and the role of biology in human welfare

We have much pleasure in presenting this book to the students and teachers of the Higher Secondary Classes and shall try to incorporate any suggestions for improvement in the next edition.

Department of Botany,
University of Delhi.

Editors: P. Maheshwari
Manohar Lal

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SECTION 2

The Diversity of Plant Life

Introduction

IN the first section of this book you had a 'bird's eye view' of the different types of plants found on the earth. You also learned that botanists group them into different categories for convenience We shall now acquaint you with the diversity of plant life a little more closely. In doing so we shall begin with the plants most familiar to you, the ones which are spread over the fields and forests and which provide mankind with the three basic necessities—food, shelter and clothing. These are the seed plants or spermatophytes including the angiosperms and gymnosperms

In the first chapter you will get an idea of the general organization of the body of an angiosperm. In the subsequent chapters you will gain a more intimate knowledge of the form, structure and function of its individual organs like the root, stem, leaf, flower and seed The subsequent chapters deal with the lower plant groups, from the viruses and bacteria to the pteridophytes. These will enable you to see how plants have gradually evolved from simple to more complex forms. The climax of this evolutionary process is seen in the seed plants themselves which possess highly specialized tissues and complex organs It is difficult to say how one group gave rise to the other but it is certain that the 'lower groups' came to occupy the earth much earlier than the higher and that the various plant forms represent some of the stages in the evolutionary history of the plant kingdom.

The reasons for starting our study with the most highly advanced group should be obvious to you. they are the most easily available, are easy to work with, and offer an excellent opportunity to everyone to study Nature in all her richness of beauty and variety

CHAPTER 10

The Plant Body

THE plants with which you are most familiar—the garden annuals, avenue trees, cereals, vegetable and fruit trees, or weeds—all belong to the same group known as the flowering plants or angiosperms They derive their name from the fact that their seeds are always enclosed in a definite organ called the ovary For example, the peas are enclosed in a pod which is a matured ovary In the whole plant kingdom the angiosperms represent the most highly developed group holding a position comparable to that of the mammals in the animal kingdom They are the most varied, useful and abundant of all the plant groups and comprise more than 200,000 species

The plant body generally consists of the root, stem, leaves, flowers, fruits and seeds (Fig 10 1). The roots are usually underground and colourless Their main function is to fix the plant in the soil and to absorb water and mineral salts. They are profusely branched and bear numerous root hairs. These are the actual absorbing organs of the root.

The stem is the aerial part on which the leaves, flowers and fruits are borne It conducts water and salts from the roots to the leaves. The leaves arise on the stem at definite points called **nodes**. There may be one or more leaves at a node. The part

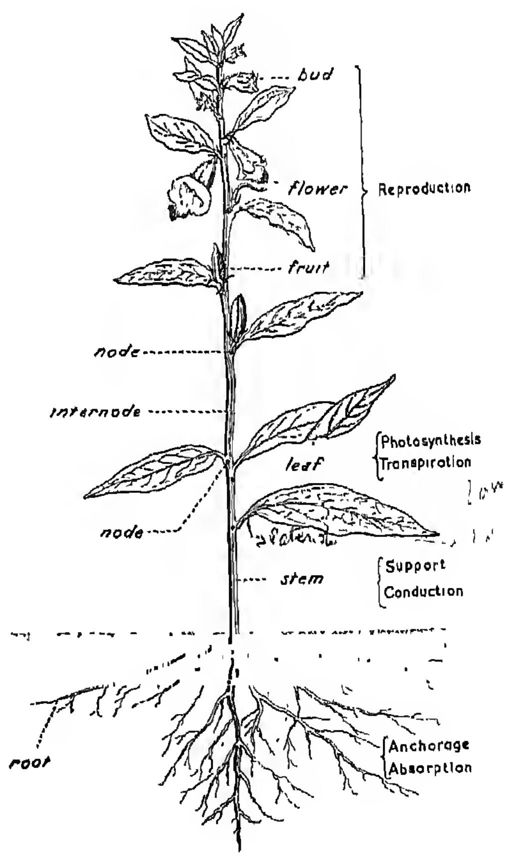

Fig. 10.1. The parts of an angiospermic plant and their functions. Courtesy of the Department of Botany, University of Delhi.

of the stem between two successive nodes is the **internode.** The angle formed between the base of a leaf and the stem is termed **leaf axil.** In each leaf axil there is a small **bud** which will grow later into a branch The bud at the extreme tip of the main stem as well as the branches grows continuously and is called the **terminal bud** or the growing point of the plant. Unlike in animals, growth in the flowering plants is localized The apices of the stem, root and their branches are the seats of growth in length

The leaves are the food factories of the plant The expanded portion, called **lamina,** is usually green and receives its water supply through the stalk or **petiole.** The lamina

Fig. 10.2. The great banyan tree (*Ficus bengalensis*) of Calcutta. The tree is said to be only 200 years old but is famous for the huge spread of its canopy. Courtesy of the Indian Botanic Garden, Calcutta.

manufactures food substances from water and carbon dioxide. The food is distributed to the other parts of the plant through the petiole and the stem. The stem thus serves as a two-way channel. It transports water and salts from the roots to the leaves and conducts the manufactured food from the leaves to the other parts of the plant

Biologically the flower is an important part not because it is so attractive but because it later on produces fruits and seeds. The seeds give rise to new plants so that the race of the parent plant is continued

This is a general picture of an angiospermic plant But the same organs may be present in greatly differing forms so that even in the same species each individual is different from the other However, one essential or distinguishing feature stands, i e., the seeds are always enclosed in an ovary In the subsequent chapters of the book you will get an idea of the diversity in the forms of plants Some angiosperms, such as *Lemna* and *Wolffia* (incidentally *Wolffia* is the smallest known angiosperm) are minute discs floating on water Others, like the eucalyptus trees, are 100 metres or more in height The great banyan tree in Calcutta (Fig. 10.2) is not so high but has such a huge spread that several scout camps can be held under its canopy The life span of the angiosperms is equally variable While small herbs like gram and pea live for only a few weeks, the famous Bodhi tree at Gaya is reckoned to be over 2000 years old

The plants which live for many years are called **perennials** while those which produce flowers and fruits in the course of a single season are known as **annuals**

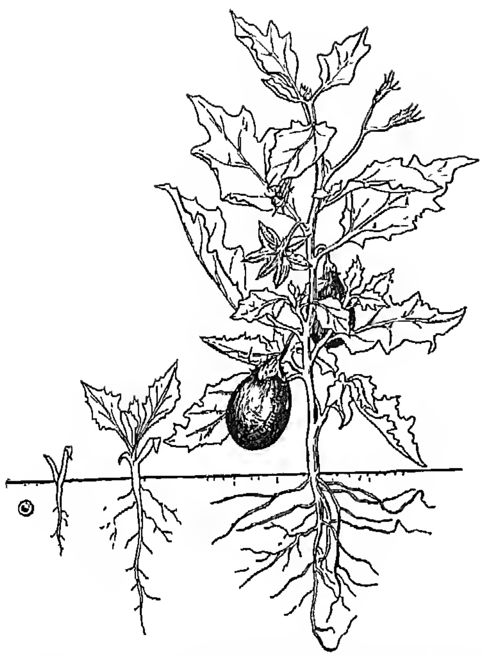

Fig. 10.3. The annual life-span. The plant completes its life cycle, from seed to seed, in the course of a single growing season without any resting stage. Courtesy of the Department of Botany, University of Delhi

(Fig. 10.3). There are still others which live for two seasons. During the first season they have only leafy stems and it is in the second that they produce flowers and fruits after which they perish (Fig. 10.4). These plants are the **biennials.**

The angiosperms are present in almost all places. They occur in the sea, on the tops of high mountains, in the scorching heat of vast deserts and in the snow fields of the arctic and antarctic regions.

The plants that grow on the soil, like most of our crop plants, are called **terrestrial** (L *terra*=earth). Those found in water are known as aquatics or **hydrophytes.** Some are perched upon other plants but do not obtain any nourishment from them These are called **epiphytes** (Fig. 10 5) They obtain their water supply from rain and from atmospheric moisture condensing on them, or from the soil and debris that settle on the bark It may surprise you to know that some epiphytes grow on telegraph wires Plants that are adapted to grow in a dry habitat, such as the cacti (Fig 10.6), are known as **xerophytes** (Gk *xeros*=dry; *phyton*=plant). The cacti and many euphorbias have fleshy stems which store water. Most plants are not specialized to grow in very dry or very wet situations but thrive under conditions intermediate between these two extremes Such plants are called **mesophytes** (Gk *mesos*=middle) and these include the great majority of our crops such as beans, tomatoes, and peas

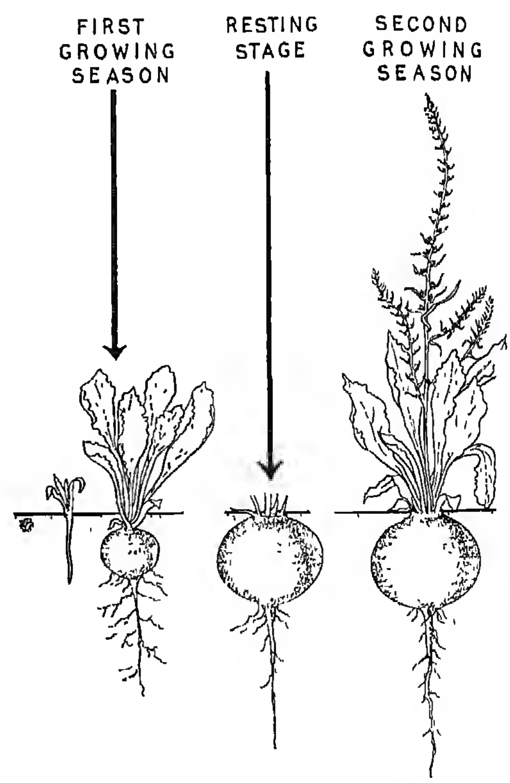

Fig. 10.4. The biennial life-span as exhibited by sugarbeet. The growth is suspended for a certain period between the two growing seasons. Courtesy of the Department of Botany, University of Delhi

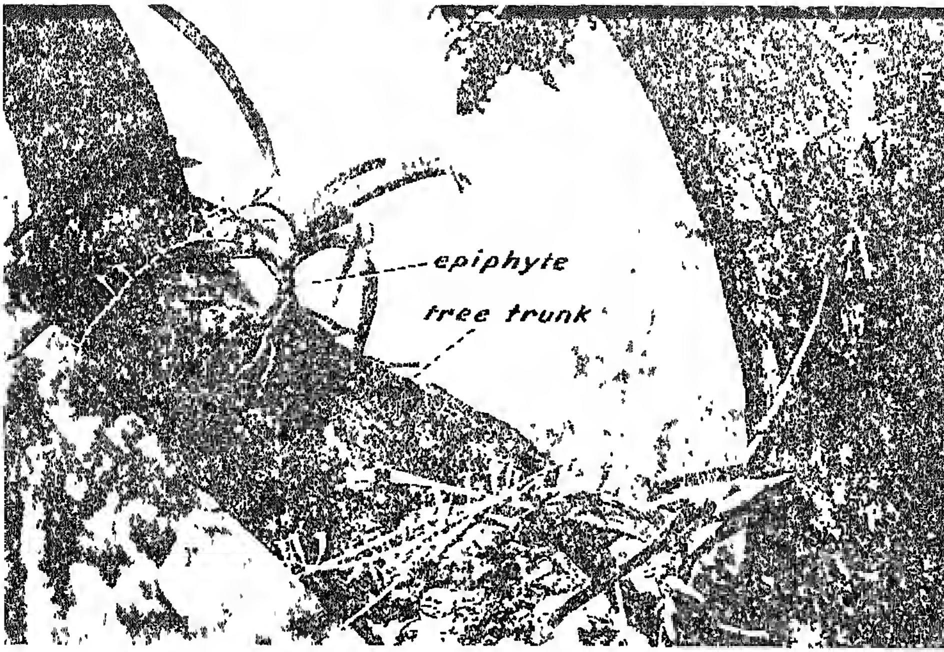

Fig. 10.5. An epiphytic orchid growing on a mango tree in Dehra Dun. The roots of the epiphyte are clearly visible. Courtesy of M.A Rau, Botanical Survey of India, Dehra Dun

Most angiosperms are independent with regard to their nutrition Those lacking chlorophyll are dependent on other plants for their nutrition and are called parasites. The dodder or *Cuscuta* is a familiar example (Fig 10 7) Its leafless, thread-like yellow stems grow on the branches of other trees and send special absorbing organs (**haustoria**) into them to obtain food and water (Fig. 10 8). The host plant often becomes weaker and seldom sets seeds because the parasite constantly robs it of its food

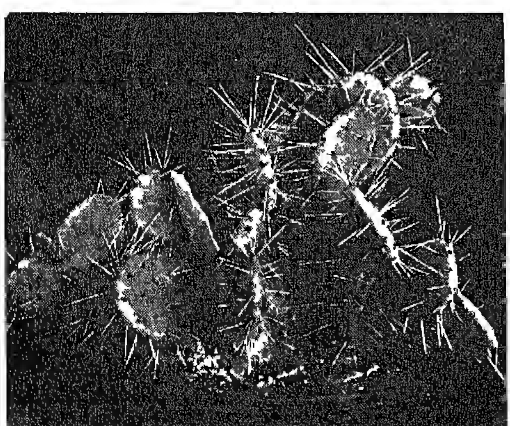

Fig. 10.6. Prickly pear (*Opuntia*) This plant can grow even in very dry areas. Note the flat, spiny and succulent stems without green leaves. Courtesy of the Department of Botany, University of Delhi

A few angiosperms have devices by which they entrap and partially devour insects, e g , the sundew (*Drosera*), the pitcher plant (*Nepenthes*), and the bladderwort (*Utricularia*). These are the **insectivorous** or **carnivorous** plants.

The angiosperms show many shades of colour, but green, red, blue and yellow are the most conspicuous. In recent years the green pigment, chlorophyll, has become very popular because of its widespread use in

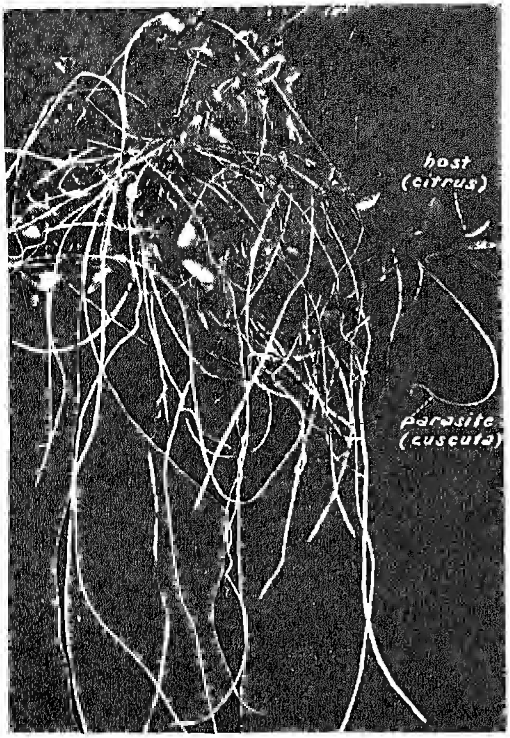

Fig. 10.7. **The parasitic dodder heavily infesting a citrus plant. The yellow, wiry stems of the parasite grow very rapidly and draw nourishment from the host plant by sending little haustoria into it.** Courtesy of the Department of Botany, University of Delhi

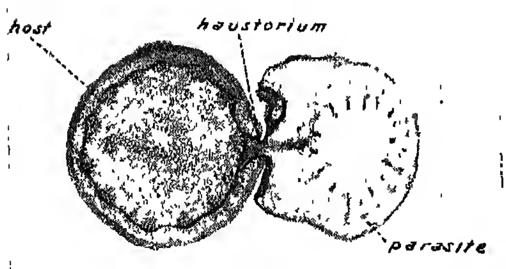

Fig. 10.8. **Transverse sections of the stems of the host and the parasite showing the haustorial connection.** Courtesy of the Department of Botany, University of Delhi.

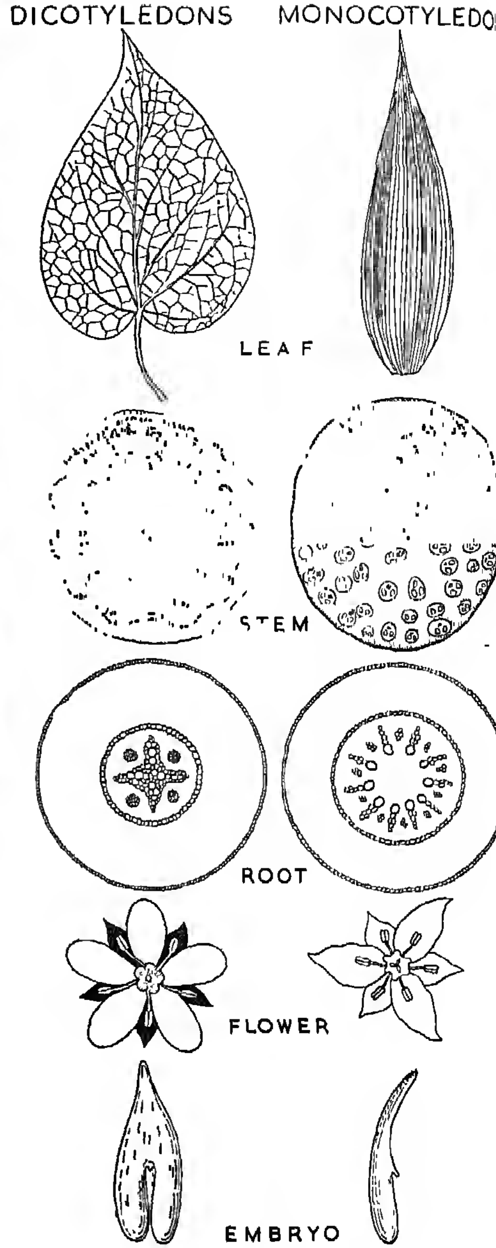

Fig. 10.9. **The main differences between the dicotyledons and the monocotyledons.** Courtesy of the Department of Botany, University of Delhi.

medicines and toilet preparations including toothpastes. Chlorophyll develops only if the plants receive light Thus, if you keep a potted plant in dark it soon turns yellow and sickly.

Red is another common colour in plants It may be present in leaves, stems, flowers, fruits and even roots. Most of the red, blue and purple colours of plants are due to a pigment called **anthocyanin.** When the cell sap is acidic, the pigment is red, when alkaline, it is blue. This can be demonstrated in the laboratory by placing blue flowers in a weak acid solution, they turn red after some time

The yellow colour is due to **carotene** and **xanthophyll.** These are found in many flowers, fruits, seeds, roots and leaves. When we consume vegetables containing carotene, the latter becomes converted into vitamin A in our bodies

One of the possible uses of colours in plants is that they attract insects You will understand the full significance of insect visits later in Chapter 15 The pigments also screen off the intense summer light, especially the ultraviolet radiations which may be injurious to the living protoplasm

Angiosperms are divided into two groups—the dicotyledons and the monocotyledons—which are quite well-marked from each other (Fig 10 9) The dicotyledons, as the name indicates, have two cotyledons or seed-leaves in the seed, while the monocotyledons have only one The two groups are also distinguished by other characters The dicotyledons have leaves with a network of veins, conducting strands in the stem arranged in a circle, roots with a star-shaped xylem, and floral parts (sepals, petals stamens and pistil) in multiples of four or five The monocotyledons, on the other hand, have leaves with parallel veins, scattered conducting strands in the stem, roots with several strands of xylem, and floral parts in multiples of three.

SUMMARY

Our most familiar plants like pea, mango and coconut come under the group known as angiosperms Here the seeds are always enclosed in an ovary

The plant body of an angiosperm generally consists of root, stem, leaves, flowers, fruits and seeds. The main function of the root is to fix the plant in the soil and to absorb water and mineral salts from it The stem conducts water and salts from the roots to the leaves and transports food materials from the leaves to the other parts of the plant. The leaves are the food factories of plants, with the help of chlorophyll they manufacture food substances from carbon dioxide and water. The flowers produce seeds by which the plant perpetuates itself.

The angiosperms are divided into two groups. dicotyledons and monocotyledons. As the names suggest, the dicotyledons have two seed-leaves or cotyledons while the monocotyledons have only one cotyledon in their seeds. The two groups can be further distinguished by several other characters.

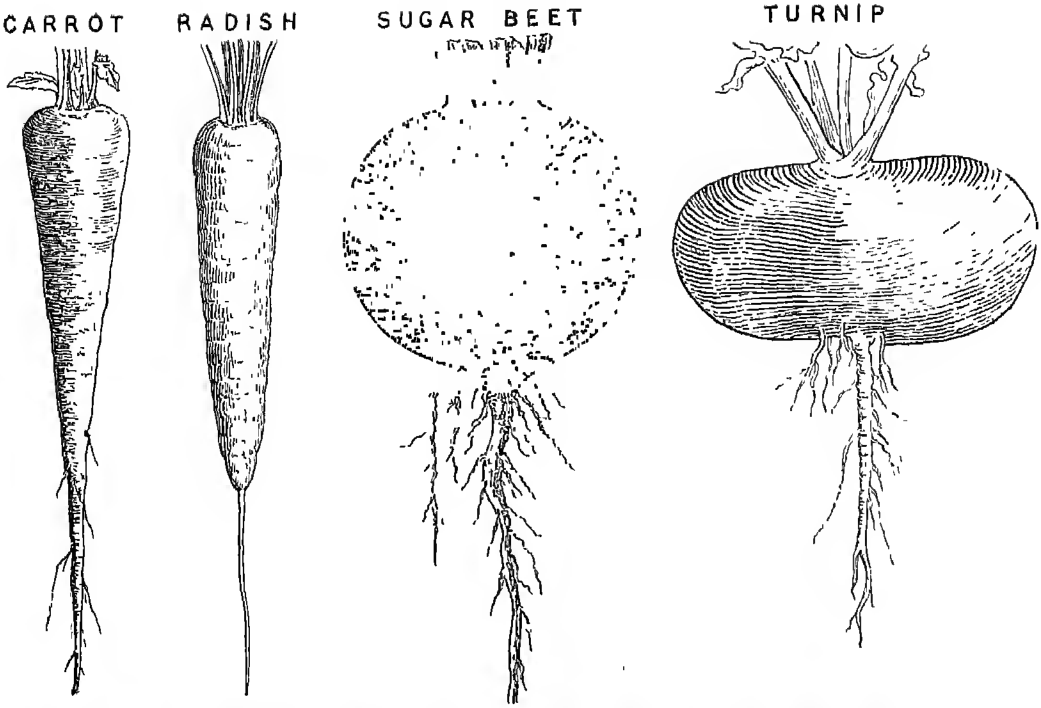

Fig. 11.2. Different types of storage roots. Courtesy of the Department of Botany, University of Delhi.

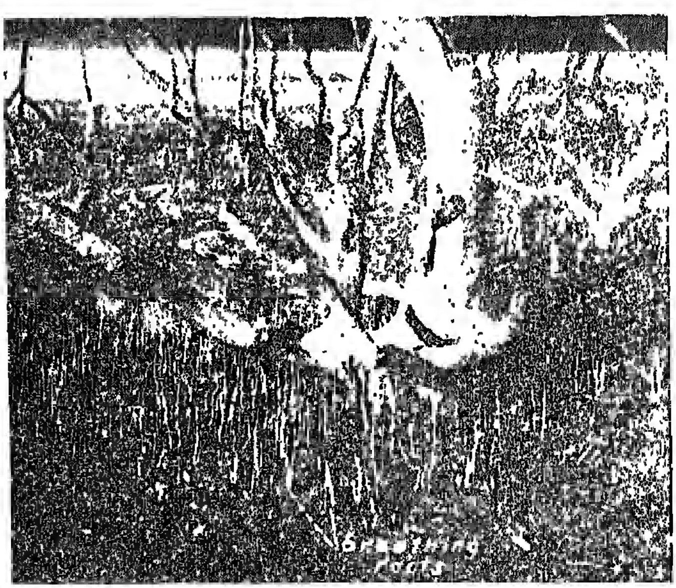

Fig. 11.3. Breathing roots of ***Ceriops roxburghiana*** **growing in the Andaman Islands.** Courtesy of K. Thothathri, Central National Herbarium, Sibpur.

ground level (Fig 11 3) These roots have a large number of minute pores through which the respiratory exchange of gases can take place. Such roots are, therefore, spoken of as 'breathing roots'

Sometimes, roots may arise from the nodal regions of the stem as in betel vine and *Pothos* (Fig 11.4) Such roots are called **adventitious** (L *adventitius*=extraordinary)

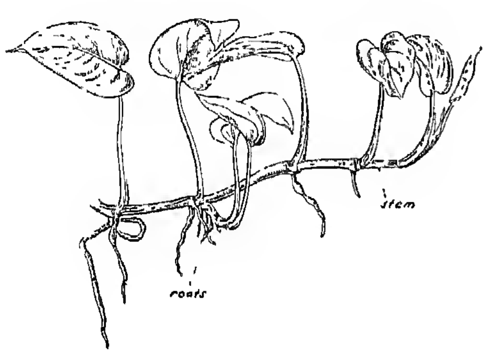

Fig. 11.4. Adventitious roots of *Pothos* Courtesy of the Department of **Botany,** University of Delhi

The primary roots of maize are shallow. Robust adventitious roots (called **stilt roots**) develop from the lower nodes of the stem and support the plant (Fig. 11.5). Similar roots are seen in *Pandanus*. The roots of some trees are partly above the ground level. They grow unequally on the periphery and their expanded exposed regions look like ribs (Fig. 11.6). The banyan tree produces numerous aerial roots which at first hang in the air but gradually descend to the ground and develop normal underground roots (Fig. 11.7). The aerial parts thicken and serve to support the branches.

Wash a young potted plant free of soil to observe the general features of the root. In contrast to the stem, the root is not differentiated into nodes and internodes, and usually lacks the green colour. The growing point or apical meristem of the root, unlike that of the stem, is covered by a

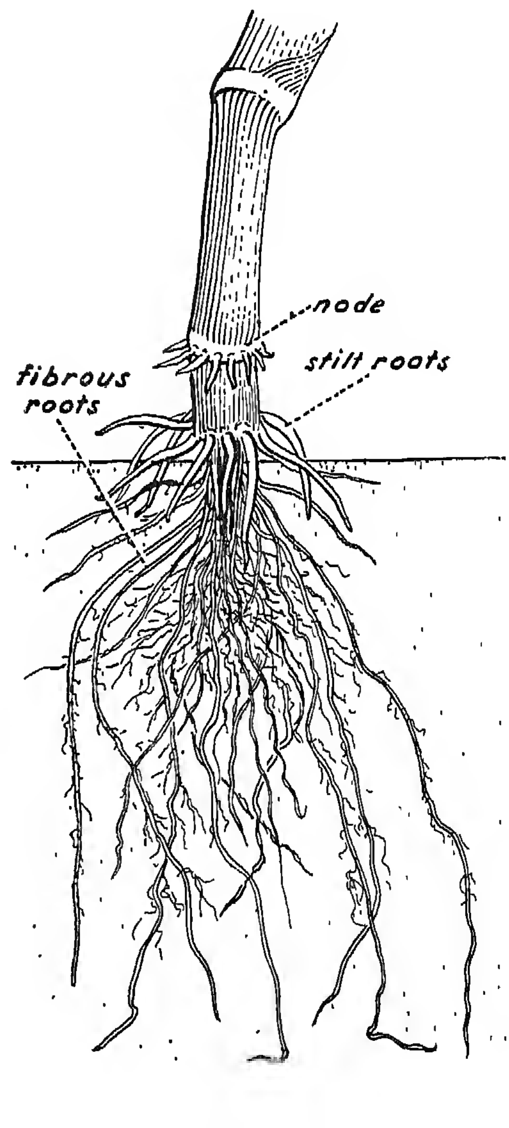

Fig. 11.5. Stilt roots of maize (*Zea mays*) These roots arise from the nodes close to the ground and provide additional support to the plant. Courtesy of the Department of Botany, University of Delhi

Fig. 11.6. Roots of *Pterygota alata*. Note the rib-like appearance due to asymmetrical growth. Courtesy of K. Subramanyam, Botanical Survey of India, Calcutta.

Fig. 11.7. Aerial roots of banyan (*Ficus bengalensis*). Each of the long, columnar trunks in this picture is an aerial root established in the soil. Courtesy of K. Subramanyam, Botanical Survey of India, Calcutta.

conical root cap made of parenchymatous cells (Fig 11 8). The outer cells of the cap are constantly worn away as the root grows forward in the soil The growing region or the meristem adds new cells to the cap as well as to the main body of the root Behind the meristematic region there is a zone which is characterized by the presence of rapidly elongating cells. This elongation zone is followed by the region of maturation, consisting of cells which have more or less completed their elongation and are differentiating to form the various tissues of the primary root. The epidermal cells of this region develop small, delicate hairy outgrowths called root hairs These are the main water absorbing organs of the plant. As the tip of the root continues to elongate, it produces new root hairs while the older ones die out During their growth from the epidermal cells, the root hairs penetrate the soil up to a distance of about two centimetres and become closely associated with the soil particles. Thus it becomes almost impossible to remove a plant from the soil without breaking most of the root hairs unless a part of the soil around the roots is also taken up with the plant.

The growing region in the root can be located by a simple experiment. On the newly emerged root of a pea or gram seedling, put some equidistant marks (about 1 mm apart) with India ink from the tip backward Allow the root to grow for a couple of days. It will be noticed that the marks immediately behind the tip become wider apart, while those further back remain almost unchanged (Fig 11.9).

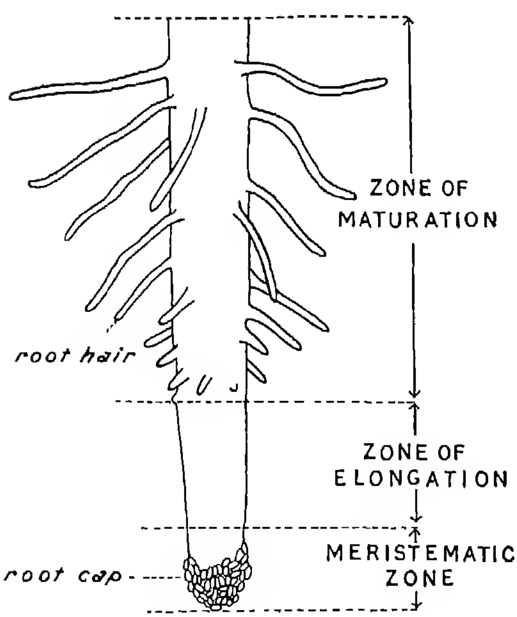

Fig. 11.8. Regions of the root. From A C Dutta, *A Classbook of Botany*, Oxford University Press, Bombay, 1959.

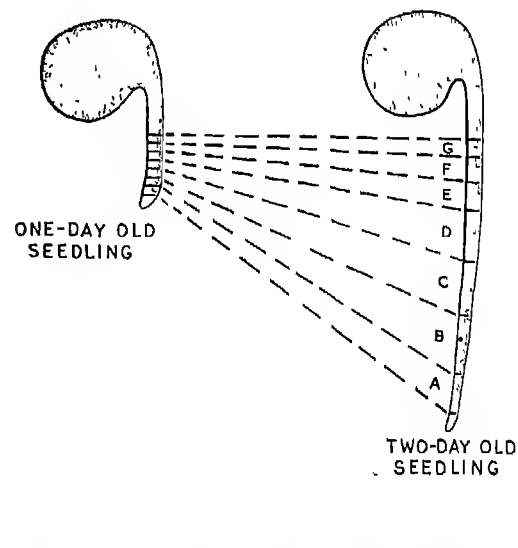

Fig. 11.9. Detection of zones of elongation by the parallel line marking technique. Zones B, C, and D immediately behind the apex show maximum elongation. After A W Galston, *The Life of the Green Plant* Foundations of Modern Biology Series, Prentice-Hall Inc, Englewood Cliffs, New Jersey, 196

Anatomy

A thin transverse section of the maize or barley root (Fig 11.10) may be examined to see the arrangement of the tissues in the root of a monocotyledon It may be noted at the outset that the tissues composing stems and roots are largely the same However, as we shall see, their arrangement in the two organs is quite different.

The outermost layer of cells is the epidermis. In a section passing through the root hair zone, the hairs are seen as tube-like projections of the epidermal cells (Fig. 11.10) Interior to the epidermis is the broad zone of **cortex** comprising thin-walled parenchymatous cells that appear to be rounded in cross section. The innermost layer of the cortex, called **endodermis,** is quite prominent in roots because of the peculiar thickenings on the inner and radial walls of its rectangular cells. One or two layers of thin-walled cells lying interior to the endodermis constitute the **pericycle.** The branch roots arise in the pericycle Some of the cells of the pericycle divide and give rise to a growing point. This gradually pushes its way through the cortex as a lateral root and enters the soil.

The vascular tissues, xylem and phloem, lie in several separate strands along the radii of the central cylinder and alternate with each other. In each xylem strand the vessels with the largest diameter occur towards the centre and the narrowest ones towards the periphery (near endodermis) The central zone is called the **pith** and generally consists of thin-walled parenchymatous cells.

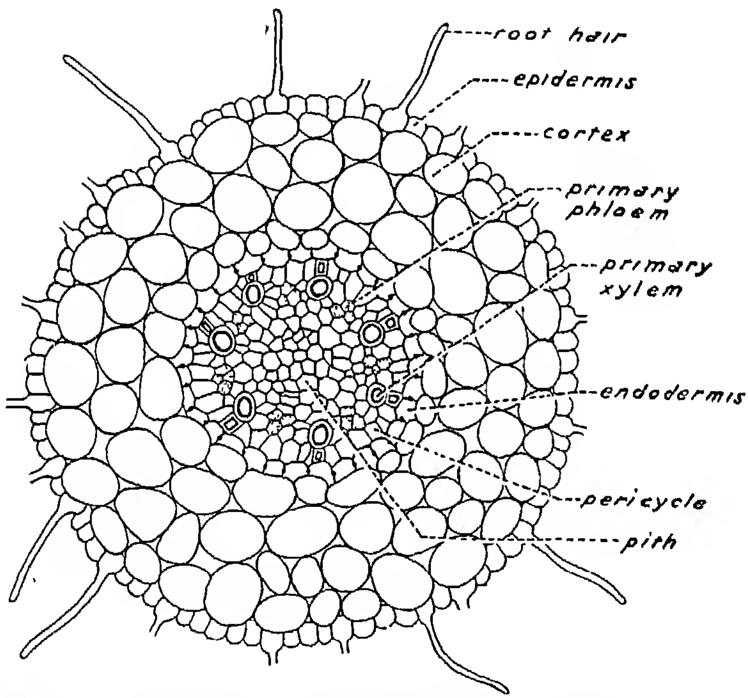

Fig. 11.10. Transverse section of a young monocot (barley) root. After C L Wilson and W E Loomis, *Botany*, Holt, Rinehart and Winston, New York, 1962.

The roots of monocotyledons always

remain thin. An increase in girth by secondary growth seldom occurs in them because they lack the special meristematic tissue or **cambium.**

The vascular tissues that are formed in a young root before it begins to increase in girth are called **primary,** while those formed later are known as **secondary.**

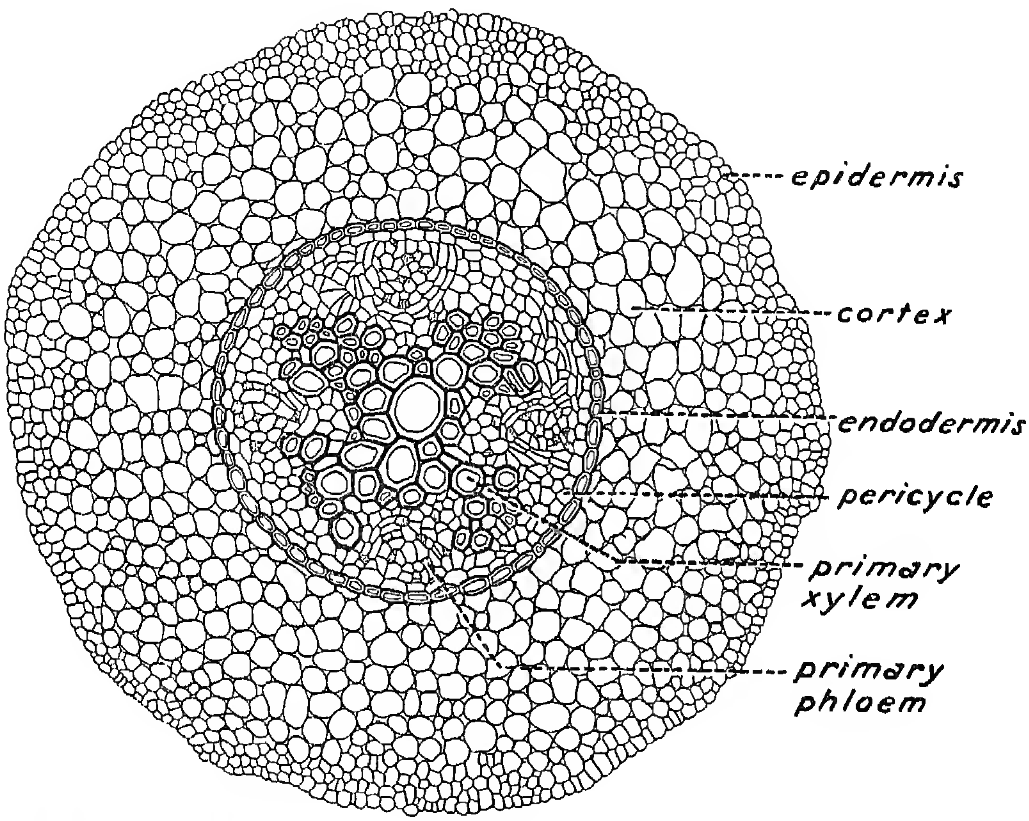

Fig. 11.11. Transverse section of a young dicot (*Phaseolus*) root. Courtesy of the Department of Botany, University of Delhi.

In the young roots of dicotyledonous plants, such as sunflower and bean, the epidermis and cortex are similar to those of a monocot root. The patches of vascular elements have the same **radial arrangement,** but the xylem and phloem strands are fewer—generally only three or four (Fig 11.11). Moreover, the xylem patches usually meet at the centre and give a star-shaped appearance in transverse section. In most cases the pith region is absent.

The roots of dicotyledons undergo a considerable increase in girth (**secondary growth**) due to the establishment of a fresh meristematic tissue, the cambium At the commencement of the secondary growth strips of cells interior to the phloem patches become meristematic (Fig 11 12 A) The strips gradually extend laterally and join each other so as to include the star-shaped xylem mass inside a ring of cambium. Active cell divisions in the cambium result in the

production of cells both on the outer as well as the inner sides (Fig. 11 12 B). The cells cut off towards the outside differentiate into secondary phloem and those cut off towards the interior into secondary xylem (Fig 11 12 C). The production of secondary xylem in the bays starts earlier so that the cambial ring soon becomes circular In later stages the patches of primary phloem become crushed and are difficult to locate.

While the vascular cambium is adding secondary xylem and phloem, another cambium, called the **cork cambium,** differentiates from the pericyclic cells (Fig. 11 12 C). It produces many more layers on the outside than on the inside The outer layers of cells form the **cork** (Fig. 11.12 D). The cortex is crushed by the enlarging tissues from within, and peels off.

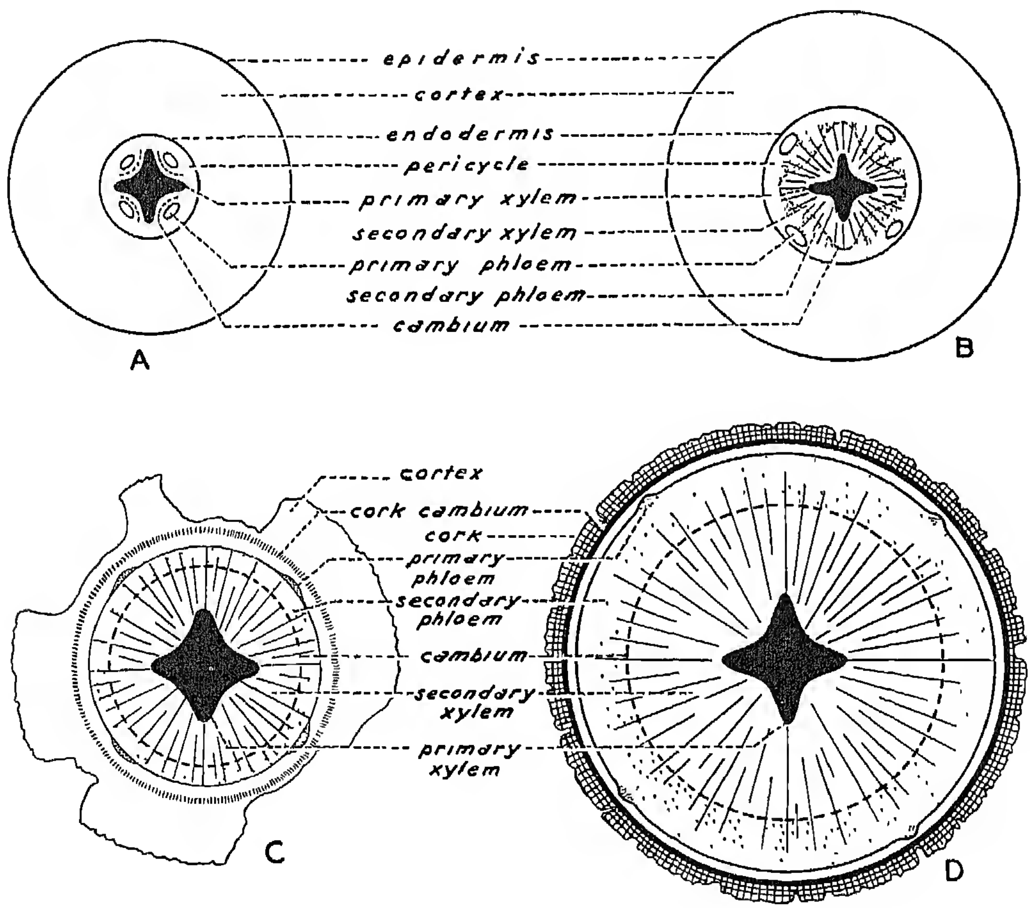

Fig. 11.12. Diagrammatic representation of transverse sections of a dicotyledonous root to show secondary growth. A. Root before undergoing secondary growth. B. Initiation of secondary growth. C. As secondary growth continues, the outer tissues slough off. D. Older root. After H J. Fuller and O. Tippo, *College Botany*, Holt, Rinehart and Winston, New York, 1954.

Absorption of Water and Minerals

The root grows in an environment of porous, moist soil containing inorganic salts in solution. The younger roots and their tufts of hairs are in intimate contact with the soil particles which are more or less bathed in a film of water (Fig 11.13). The concentration of water in the soil is usually higher than that in the root hairs and, therefore, water diffuses into them. From the root hairs water moves into the adjoining cortical cells, then into the endodermis and pericycle, and finally into the xylem (Fig. 11.14). Inorganic salts in solution enter the root hairs with the water. From the younger roots water and salts diffuse into the main roots through which they are conducted to the aerial parts, i.e. the stem, leaves, flowers and fruits.

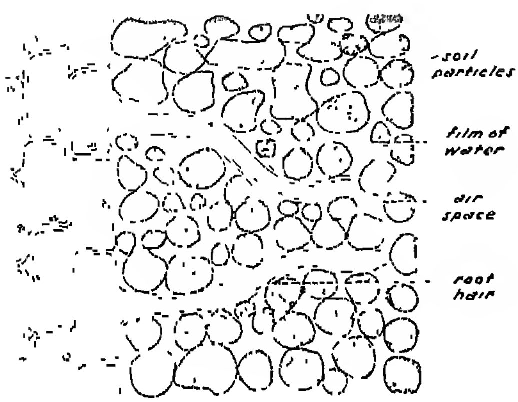

Fig. 11.13. Root hairs in contact with soil particles. A film of water surrounds each particle. Note also the air-filled spaces in the soil. Courtesy of the Department of Botany, University of Delhi.

Uses

Many roots such as the carrot and radish are used raw or cooked. The sweet potato is boiled or roasted before eating. Tapioca roots are a rich source of starch and are much used in Kerala. The starch extracted from them is made into synthetic rice and sago. Beet root, which is used in our country only as a vegetable, is the chief source of sugar in European countries.

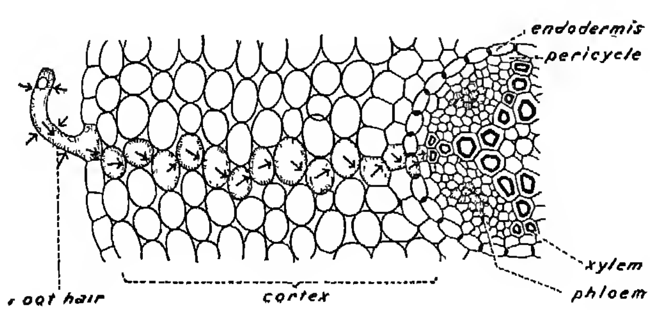

Fig. 11.14. Transverse section of a root showing the path of water from a root hair to xylem. After A.C Dutta, *A Classbook of Botany*, Oxford University Press, Bombay, 1959.

SUMMARY

Roots are the non-green, usually underground, parts of a plant. They absorb water and inorganic salts from the soil and conduct them to the leaves through the stem They also serve to anchor the plant in the soil.

In the tap root system the primary root becomes the main part of the system while in the fibrous root system there are numerous slender main roots of almost equal size. Adventitious roots arise from the nodes of the stem

The tip of the root is covered by a root cap. Above this there are three distinct zones known as the meristematic zone, elongation zone and maturation zone.

The arrangement of the tissues in a young root, from the periphery inwards, is as follows· epidermis, cortex, endodermis, pericycle, vascular elements, and pith. The roots of dicotyledons differ from those of monocotyledons in having fewer (2-5) xylem and phloem strands and in the absence of a broad pith.

The older roots of dicotyledons develop a cambium from the parenchymatous cells lying between the xylem and the phloem groups. The cambium cuts off secondary xylem towards the inside and secondary phloem towards the outside This results in an increase in the thickness of the root.

The side roots and the periderm develop from the pericycle The root hairs arise as protuberances from the outer walls of the epidermal cells The absorption of water by the root occurs mostly through the root hairs

The roots of many kinds of plants are used as food and as the source of several drugs.

QUESTIONS

1. When seedlings are transplanted, a good many fail to grow in the new soil. From your knowledge of root morphology, think of a possible reason for this.
2. Make a labelled diagram of a one-year-old dicot root without showing any cells.
3. Explain the following terms in your own words:
   (a) stilt roots, (b) cork cambium; (c) adventitious roots; (d) endodermis; (e) root cap.
4. Name some useful products obtained from roots.

FURTHER READING

ANONYMOUS 1963. The Root. *Understanding Science* Vol. 4 No. 40 pp. 630-631.

BROWN, W.H. 1935. *The Plant Kingdom: A Textbook of General Botany.* Ginn and Company, London.

CHAPTER 12

The Stem

THE stem is a part of the supply line for the manufacture of food materials in Nature's factory, the leaves It produces leaves and flowers, and displays them to the best advantage of the plant The leaves are so arranged that they receive sufficient light and do not shade one another too much. The green outer tissues of the young stem can also synthesize food materials themselves.

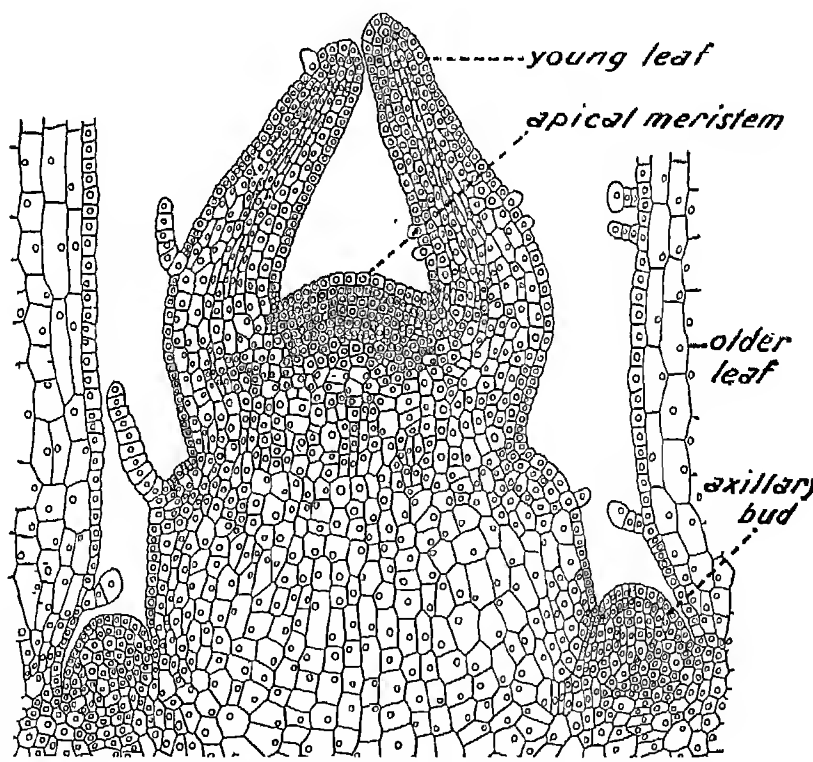

Fig. 12.1. Longitudinal section of stem tip of *Coleus.* From A W. Haupt, *Plant Morphology*, McGraw-Hill Book Company, Inc., New York, 1953.

Stems, which are soft and do not grow very much in diameter, are known as **herbaceous.** You are familiar with many ornamental and crop plants such as marigold, wheat, maize and pea, which have such stems and are therefore called herbs. The stiffness of herbaceous stems is often due to the turgidity of the cells. This is advantageous in keeping the plants erect.

Trees have a woody trunk which grows continuously in length as well as thickness

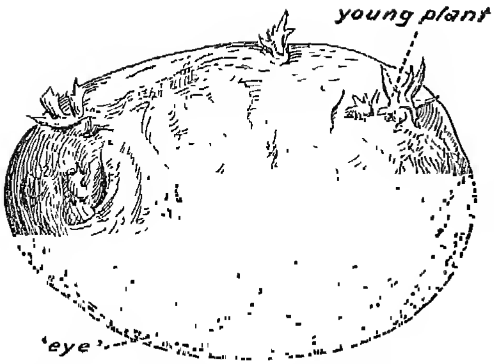

Fig. 12.6. Potato tuber, a modified underground stem. The depressions or 'eyes' contain the buds. Courtesy of the Department of Botany, University of Delhi

soon becomes underground. On the surface of the tuber are a number of buds popularly known as 'eyes', from which new plants can develop. The potato tuber is full of reserve food material in the form of starch.

The stem of onion is highly reduced. It is merely a short, convex or slightly conical disc bearing white or pink fleshy leaves surrounded by outer papery leaves (Fig. 12.7) Adventitious roots are produced

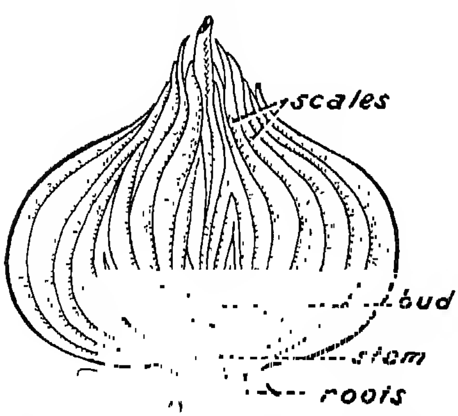

Fig. 12.7. Bulb, the reduced and modified stem of onion (*Allium cepa*), in longitudinal section. Courtesy of the Department of Botany, University of Delhi.

from the base of the reduced stem The disc-like stem with the leaves is called a **bulb.** The fleshy leaves store food while the dry scales give protection In the centre, near the base of the fleshy leaves, is situated the terminal bud surrounded by several axillary buds.

Sometimes the stem becomes green and leaf-like as seen in *Opuntia* and *Ruscus* (Fig. 12.8) Such a flattened stem is called a

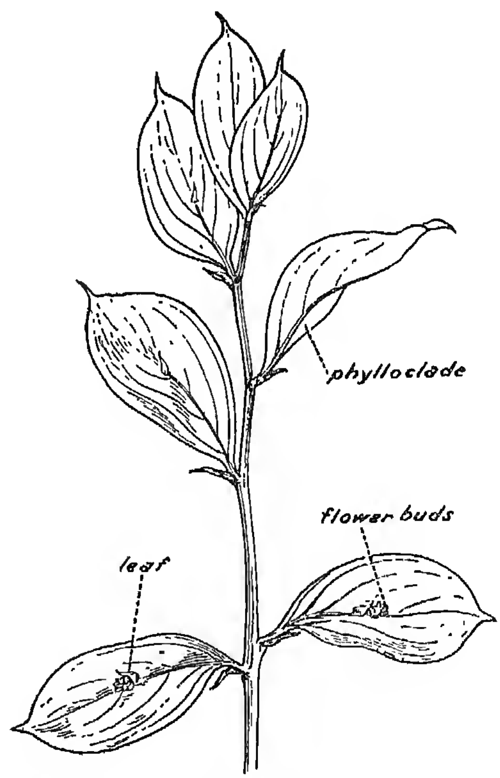

Fig. 12.8. Flattened leaf-like stems (phylloclades) of *Ruscus* Note the small scaly leaves. Courtesy of the Department of Botany, University of Delhi.

phylloclade. Since the leaves on these stems are small and short-lived, excessive loss of water from the plant is prevented.

The stems of some plants are covered with hairs. In the stinging nettle (*Urtica*) these

hairs have a stiff tip. When a hair comes in contact with the body of a human being or animal, its tip breaks and the cell sap is injected into the skin, causing a severe irritation which is sometimes very troublesome

Anatomy

The growing point of the stem shows three regions. There is a meristematic zone of actively dividing cells at the apex. Below it is a zone of elongating cells and then a region of maturing cells (Fig 12 1). An important difference from the root is the absence of a root cap and the presence of tiny primordia which later mature into leaves.

Examine a cross section of a mature monocotyledonous stem (Fig 12.9). It shows a distinct epidermis and numerous vascular bundles lying scattered in the parenchymatous ground tissue. The vascular bundles are smaller and more numerous

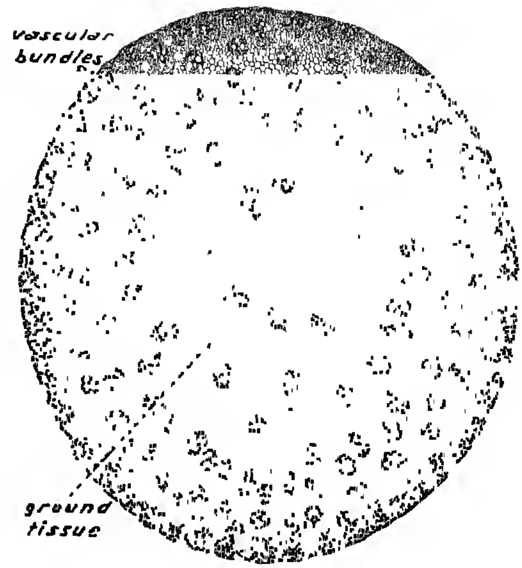

Fig. 12.9. Cross section of a monocotyledonous stem, *Zea mays*. From W.H Brown, *The Plant Kingdom A Textbook of General Botany*, Ginn and Company, Boston, 1935

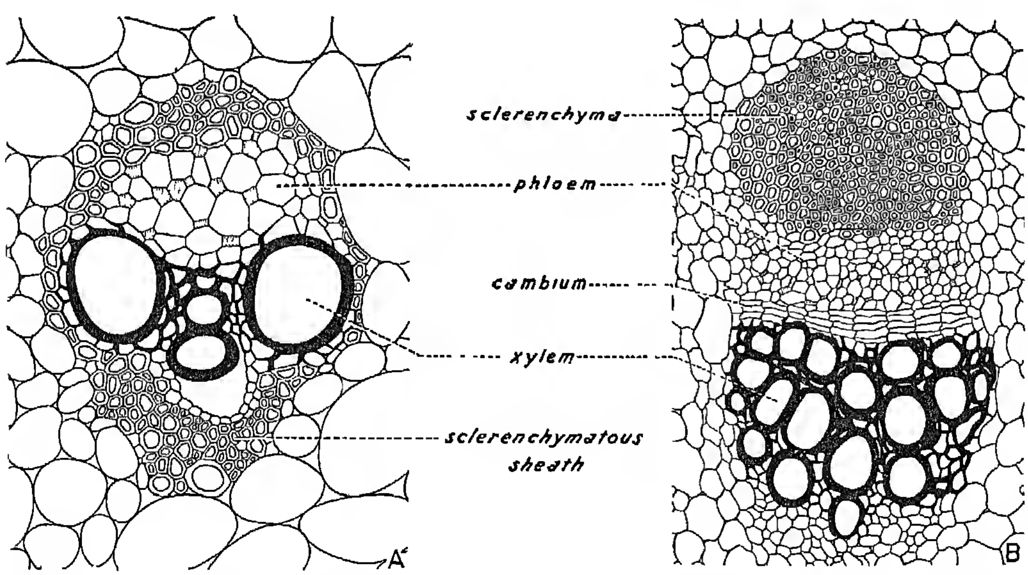

Fig. 12.10. Enlarged view of vascular bundles from the transverse section of a monocotyledonous (A) and of a dicotyledonous (B) stem. The monocotyledonous bundle lacks cambium and is surrounded by a sclerenchymatous bundle sheath. In the bundle from the dicotyledonous stem a cambium is present, while the bundle sheath is absent. Courtesy of the Department of Botany, University of Delhi.

towards the periphery than towards the inside. In contrast to roots where the xylem and phloem patches occur alternately, in the stem these tissues are present in the same vascular bundle. The phloem occupies the outer part of the bundle (towards the epidermis), while the xylem is situated on the inner side The bundles are often surrounded by a sheath of thick-walled (sclerenchymatous) cells (Fig. 12 10 A). The arrangement of the vessels is typically V-shaped with the smaller elements or protoxylem at the inner end and the larger ones or metaxylem at the sides or towards the outside.

In a dicotyledonous stem (Fig. 12.11 A) the arrangement of the tissues is in some ways quite different There is the usual epidermis followed by a broad or narrow zone of cortex, and the central region of vascular bundles. However, these are arranged in a ring instead of being scattered Another important feature is that between the phloem and xylem there is a strip of meristematic cells, the cambium (Fig 12.10 B) The cambium is responsible for the secondary growth and the consequent thickening of the stem. The central region of the stem (pith) is made of thin-walled, parenchymatous cells.

When the cambium becomes active, the new cells produced by its divisions mature into secondary xylem towards the inside and secondary phloem towards the outside Strips of cambium also differentiate between adjacent bundles These join with the cambium of the bundles to form a complete ring (Fig 12 11 B) In a woody stem secondary xylem and phloem are also produced in between the bundles (Fig. 12.11 C) As more and more of the secondary tissues are formed, the primary xylem is pushed towards the centre of the stem and the primary phloem towards the cortex (Fig. 12.11 D). Whereas the primary phloem becomes crushed, the primary xylem persists. This is because the phloem consists of thin-walled cells while the xylem is made up of thick, lignified cells

The secondary xylem is usually spoken of as wood It is composed of vessels, tracheids, fibres and parenchyma In old stems the wood shows an outer area (**sapwood**) of lighter colour consisting of actively functioning tissues. Inner to the sapwood is a solid cylinder called the **heartwood** (Fig. 12 12) The tissues of the heartwood are dead and are often filled with gums and resins which give it a characteristic colour The sapwood conducts water and minerals up the stem while the heartwood gives only mechanical strength.

In temperate countries the tissues of the secondary xylem formed during the spring are broader than those produced during the autumn The spring and autumn woods stand out in the form of a ring. Since one such ring is formed every growing season, it is called a **growth ring** (Fig. 12.13). One can estimate the age of a tree by counting the growth rings in its stem When the seasons are not well-marked, the spring and autumn woods do not show much difference. This is the reason why growth rings are not so clear in tropical plants.

When secondary xylem is being formed, some of the radial strips of tissue produced by the cambium do not differentiate into xylem and phloem but remain parenchymatous. These strips constitute the **vascular rays** and may either run from xylem through phloem or may be limited only to xylem or to phloem (Fig. 12 11 E). The vascular rays appear like the spokes of a wheel, and are quite prominent in some woods.

Depending on its structure and composition, the wood may be light or heavy. The lightest wood is that of balsa (*Ochroma lagopus*) and the heaviest is that of *Guiacum*

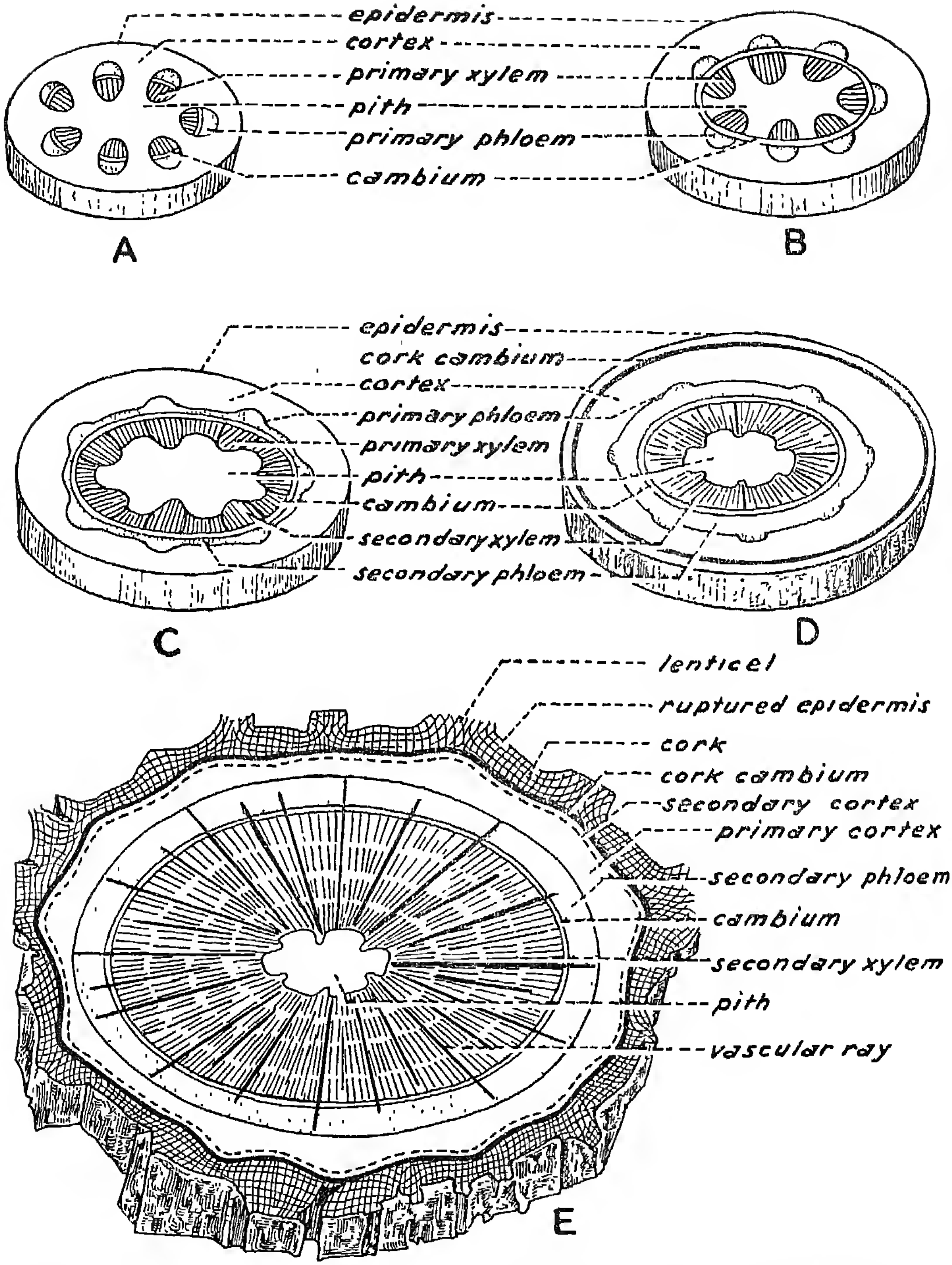

Fig. 12.11. The primary and secondary structure of a dicotyledonous stem (all figures drawn in transverse section). During the secondary growth a complete ring of cambium is formed which produces secondary xylem towards the inside and secondary phloem towards the outside. Courtesy of the Department of Botany, University of Delhi.

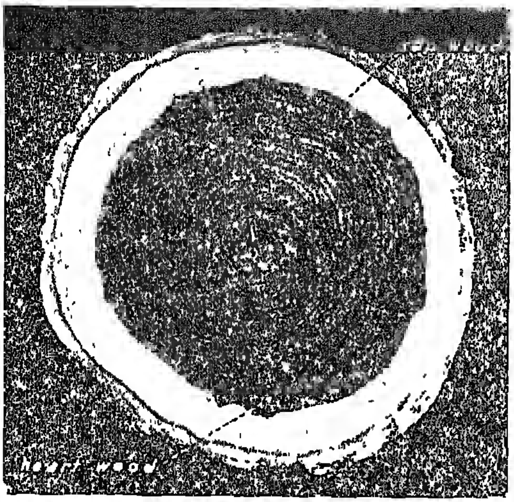

Fig. 12.12. Cross section of the stem of 'sisham' (*Dalbergia sissoo*) showing the cylinder of heartwood surrounded by sapwood. Courtesy of the Department of Botany, University of Delhi

officinale. A somewhat comparable heavy wood from India is that of *Acacia sundra* (Fig. 12.14).

With the expansion of the vascular cylinder

Fig. 12.13. Cross section of the wood of *Cedrela* showing growth rings. Courtesy of the Department of Botany, University of Delhi.

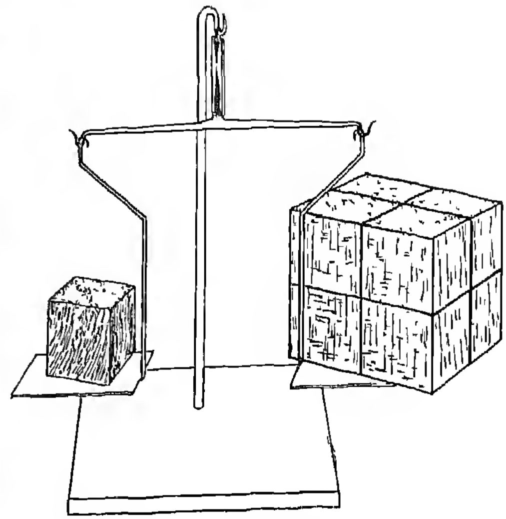

Fig. 12.14. The volume of an equal weight of heavy wood (*Acacia sundra*) and light wood (balsa, *Ochroma lagopus*) compared. Courtesy of the Department of Botany, University of Delhi

considerable pressure is exerted on the cortex. To accommodate this expansion from the centre, there is a provision to increase the circumference. One of the outer layers of the cortex becomes meristematic. This is the cork cambium (Fig. 12.11 D). Its cells divide repeatedly. The daughter cells cut off towards the epidermis differentiate into a tissue called cork while those cut off towards the phloem form the secondary cortex (Fig. 12.11 E). The cork is made up of dead cells whose walls become waterproof due to the deposition of suberin. As new cork is formed, the outer layers of the cork as well as the cortex peel off and are popularly called **bark.** The bark protects the stem from mechanical injury, disease and loss of water. One of the most remarkable barks is that of 'bhojpatra' (*Betula utilis*)—a tree very common in the forests of Madhya Pradesh. The bark peels off in large, thin sheets (Fig. 12.15). Many of our ancient scriptures are written on pieces of this bark (Fig. 12.16).

Fig. 12.15. Removing a sheet of bark from a branch of 'bhojpatra' tree (*Betula utilis*). Courtesy of Ramesh Bedi, Hardwar

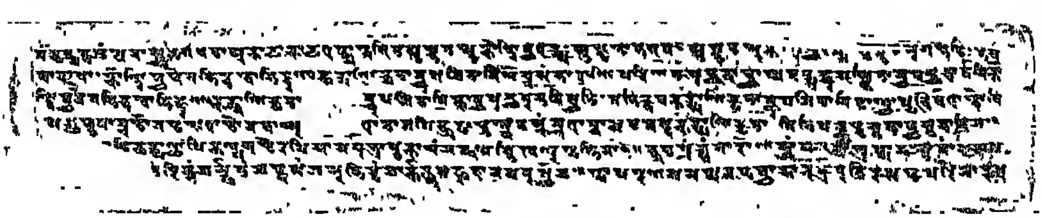

Fig. 12.16. An ancient Indian scripture written on the bark of 'bhojpatra'. Courtesy of the National Archives of India, New Delhi

Small openings called **lenticels** are present on the bark and facilitate an exchange of gases. Externally, they appear as scars or small eruptions on the surface of the stem (Fig. 12.17). Each lenticel consists of a loose mass of small, thin-walled cells. Lenticels are formed from the cells derived from the cork cambium which, instead of maturing into compact rows of cork cells, remain thin-walled. Usually a lenticel develops below a stoma and as it increases in size the epidermis becomes ruptured (Fig. 12.18).

Functions

The tissues of the sapwood carry water and mineral salts from the roots to the leaves. This process is called conduction. The mineral salts are used in the preparation of complex organic compounds in the leaves. These in turn are carried to the roots and other parts through the phloem tissues in the stem. Thus, there is a two-way transport: water and minerals go upward and food materials move downward. During their passage

Fig. 12.17. Surface of the bark of papyrus tree (*Broussonetia papyrifera*) **showing the lenticels.** Courtesy of the Department of Botany, University of Delhi

through the xylem and phloem, water and food materials also diffuse laterally and the tissues of the entire stem obtain their requirements in this way. A tree can be killed by cutting a deep ring through the phloem of its trunk since this would stop the transport of food materials to the roots.

Stem cuttings of plants like rose and sugarcane can take root and give rise to new plants. Modified stems like runners, suckers, rhizomes, bulbs and tubers also serve a similar purpose.

Uses

A large number of useful products are derived from stems. We may consider three important commodities sugar, from sugarcane, rubber, from *Hevea braziliensis*; and jute from *Corchorus capsularis* and *C. olitorius*.

Sugar is synthesized in the leaves of sugarcane and is stored in the stem It is extracted by crushing the cane Rubber is derived from a milky juice (called **latex**) produced in special tubes present in the bark of the rubber tree. When a slit is made on the stem, the latex flows along the cut edge and is collected in a cup. After treatment with several chemicals the latex is coagulated into blocks of rubber Jute is obtained from fibres occurring in the phloem of the stem of *Corchorus*. The stems are immersed in pools or tanks for a few days until the softer tissues rot due to bacterial activity. This process is known as **retting**. The fibres are then loosened by whipping the stems on the surface of water. The long, pale-yellow fibres are quite stiff and lustrous.

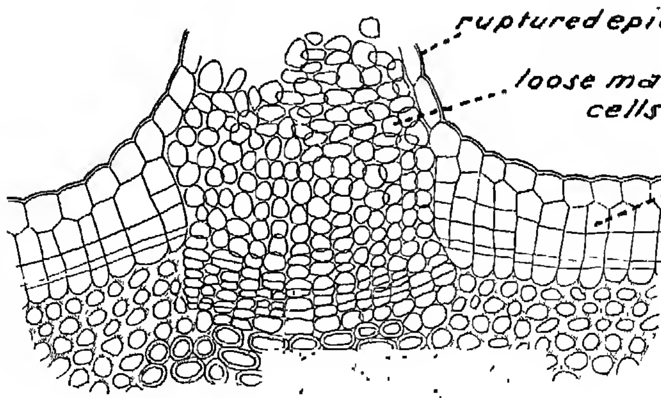

Fig. 12.18. Lenticel of *Sambucus* **in transverse section of stem.** From H. Molisch, *Anatomie der Pflanze*, Verlag von Gustav Fischer, Jena, 1936

A few other examples of commercially important products derived from stems may also be mentioned. Cork comes from the bark of *Quercus suber* and is used not only as a stopper for bottles but is of great importance in many industries. Linoleum, used as a cover for floors, is prepared from ground up cork and linseed oil Quinine, which is the only natural drug against malaria, is extracted from the bark of several species of *Cinchona*. Timber is used for house-building, furniture, railway sleepers and in numerous other ways The best timber is derived from teak (*Tectona grandis*), rose-wood (*Dalbergia latifolia*), 'sisham' (*Dalbergia sissoo*) and 'sal' (*Shorea robusta*). 'Katha', which is eaten with lime and betel leaves, is extracted from the wood of the cutch tree (*Acacia catechu*).

SUMMARY

The stem together with the leaves forms the shoot The chief functions of the stem are (1) conduction of water and mineral salts from the roots to the leaves and the transport of organic food from the leaves to the roots, flowers, fruits and buds; (2) the production and support of leaves and branches, (3) propagation, and (4) the storage of food.

In some plants stems have modified forms such as rhizome, runner, sucker, bulb, and phylloclade Even tendrils are sometimes modified branches of the stem.

Stems grow in length by the division and enlargement of the cells at the tip. The growing tip has three well-marked regions. a region of cell division, a region of cell enlargement and a region of cell maturation.

The vascular bundles in the stem of a dicotyledon are arranged in a ring and each bundle has cambium between xylem and phloem. The other parts of a young dicot stem are the epidermis, cortex, endodermis and pith. The vascular bundles in the stem of a monocotyledon are scattered and lack cambium.

Woody stems grow in diameter by the activity of the cambium. It produces secondary xylem towards the inside and secondary phloem towards the outside. The secondary xylem is popularly known as wood and constitutes the bulk of a tree.

In temperate countries and in those parts of the tropics where there are well-marked wet and dry seasons, the secondary xylem is formed in definite rings, usually one per year. Each ring consists of a zone of large cells (spring wood) and a zone of small cells (autumn wood). When the rings are well-marked, the age of a tree can be estimated by counting the rings at the base of the trunk. After a few seasons of secondary growth a new protective tissue, called the bark or periderm, develops from the cork cambium. The outer layers of the periderm are composed of the dead cork cells while the inner layers contain thin-walled living cells.

Many useful products are derived from stems The most important of these are sugar and fibres. From thicker stems we obtain timber which can be used in many different ways.

QUESTIONS

1. Describe the main functions of the stem How is it suited to conduct food materials?

2. A young boy wanted to compare the rate of his growth with that of a small tree in the compound of his house. He struck a nail in the trunk of the tree at his own height (1 5 metres) from the ground. Considering that the tree grew in height at the rate of 0.5 metre a year, where will he find the nail after (a) one year, (b) five years, (c) ten years, and (d) fifteen years?

3. What is the difference between primary and secondary tissues?

4. Write what you have learned about (a) lenticels, (b) bark, (c) secondary xylem, (d) a vascular bundle from a monocot stem, and (e) the cambium.

5. Name ten useful products obtained from the stems of angiosperms.

6. A classmate of yours prepared a microscope slide of a transverse section of a young woody angiosperm. He forgot whether it was cut through a young stem or a root. How can you help him in identifying the section?

7. Account for the following
   (a) Grafting of stems is successful in most dicotyledons but not in the monocotyledons.
   (b) Growth rings are generally well-marked in trees growing in Simla but not in those found near Bombay or Madras

8. How does the stem tip differ from the root tip? In what way do they resemble each other?

9. Name a tree which has no bark, sapwood or heartwood.

10. What makes one sample of wood more durable than another?

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ER 13

The Leaf

are the food factories of the They prepare sugar from dioxide and water in the light. The sugars are then diverse compounds found in

Ficus religiosa) may be studied tive (Fig. 13.1 A). It has a t structure called the lamina. below the lamina is the mina has a network of veins. 1 xylem and phloem elements inuous with similar tissues of h those of the petiole.

single lamina is called **simple** ng a number of distinct units common stalk is spoken of as Sometimes two small lateral s called **stipules** are present e leaf as seen in rose. Every n its axil. There are no buds e leaflets of a compound leaf

is sometimes flattened and ce as in many Australian 3 2 A). In some leaves such *natis* (Fig 13 2 B) the petiole its margin, apex and base show considerable variation. Some simple and compound leaves are shown in figure 13.1.

A large compound leaf may sometimes be mistaken for a branch, but careful observation will reveal several differences. A compound leaf does not have a terminal bud whereas a branch does. A compound leaf bears an axillary bud whereas a branch itself arises in the axil of a leaf. Moreover, the leaflets of a compound leaf do not have buds in their axils whereas the leaves on a branch always possess buds.

The veins and veinlets may run parallel to each other as in the leaves of the monocotyledons or they may form a network as in those of the dicotyledons.

A curious modification of the leaf occurs in certain insectivorous plants. In *Sarracenia* and *Nepenthes* (Fig. 13.4 A and B), for example, the leaf forms a pitcher for catching insects. In the sundew (*Drosera*) the upper surface of the leaf is covered with glandular hairs which are sensitive to touch and capture insects (Fig. 13.4 C). In *Utricularia*, a floating aquatic plant (Fig.

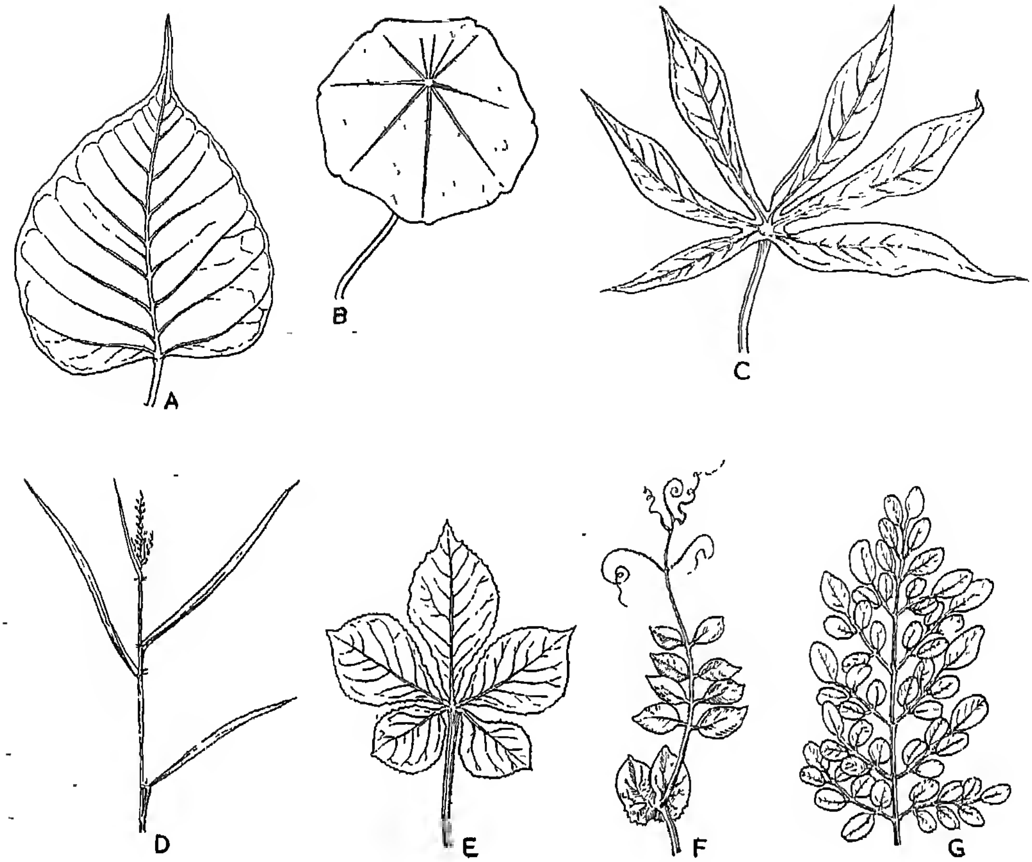

Fig. 13.1. Common types of simple (A-D) and compound (E-G) leaves. A. Pipal (*Ficus religiosa*). B. Garden nasturtium (*Tropaeolum majus*), the stalk is attached in the middle of the circular lamina. C. Tapioca (*Manihot utilissima*), the leaf is deeply lobed and simulates a compound leaf. D. Long and narrow leaves of grass; the stalk (sheath) is also leafy and clasps the stem. E. *Cleome gynandra*, the five leaflets arise from the same point on a common stalk. F. Pea (*Pisum sativum*), the terminal leaflets are modified into tendrils. G. Doubly compound leaf of *Cassia* Courtesy of the Department of Botany, University of Delhi.

'bladderwort'. With the current of water minute aquatic animals get into the bladders and are digested there

The size of the leaves varies widely. The leaves of *Monstera deliciosa* have a length of one to two metres. An interesting feature is that portions of the lamina between the veins die and fall off leaving broad holes. Perhaps the largest known leaves are those of the giant water lily (*Victoria regia*). The circular leaves with raised margins (Fig. 13.5) have a diameter of two metres or more. They are so strong that they can support a baby weighing 4 kg. This plant is a native of South America but is cultivated in numerous botanical gardens all over the world. The leaves of the coconut palm and banana are other examples of large leaves.

Some leaves appear red due to the formation of anthocyanin which is dissolved in the cell sap. Others appear brown due to the death of tissues and the production of tannic acid within them In bright sunlight such leaves lend a colourful appearance to the landscape This phenomenon is termed **autumn colouration.**

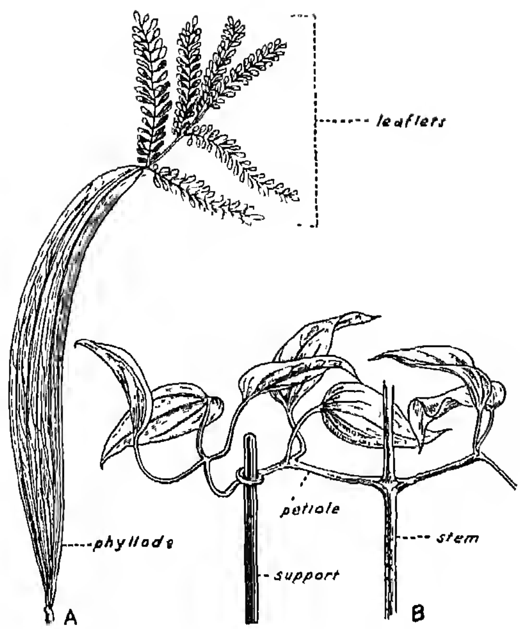

Fig. 13.2. **Leaves with modified petioles. A. Leaf from a seedling of Australian acacia (*Acacia auriculiformis*) with the petiole modified into a leaf-like structure (phyllode). B. Leaves of *Clematis* with twining petioles.** Courtesy of the Department of Botany, University of Delhi

Fig. 13.3. **A part of the bladderwort plant (*Utricularia*) Some of the leaf segments have become modified into bladders.** Courtesy of M M Johri, Department of Botany, University of Delhi.

Some trees shed all their leaves every year and are therefore called **deciduous.** The 'evergreen' trees, on the other hand, always bear some leaves The leaf-fall is due to the formation of a special layer of cells (**abscission layer**) at the base of the petiole (Fig 13 6). In temperate regions, shortly before leaf-fall, the chlorophyll disintegrates and the yellow pigments like carotene and xanthophyll become prominent.

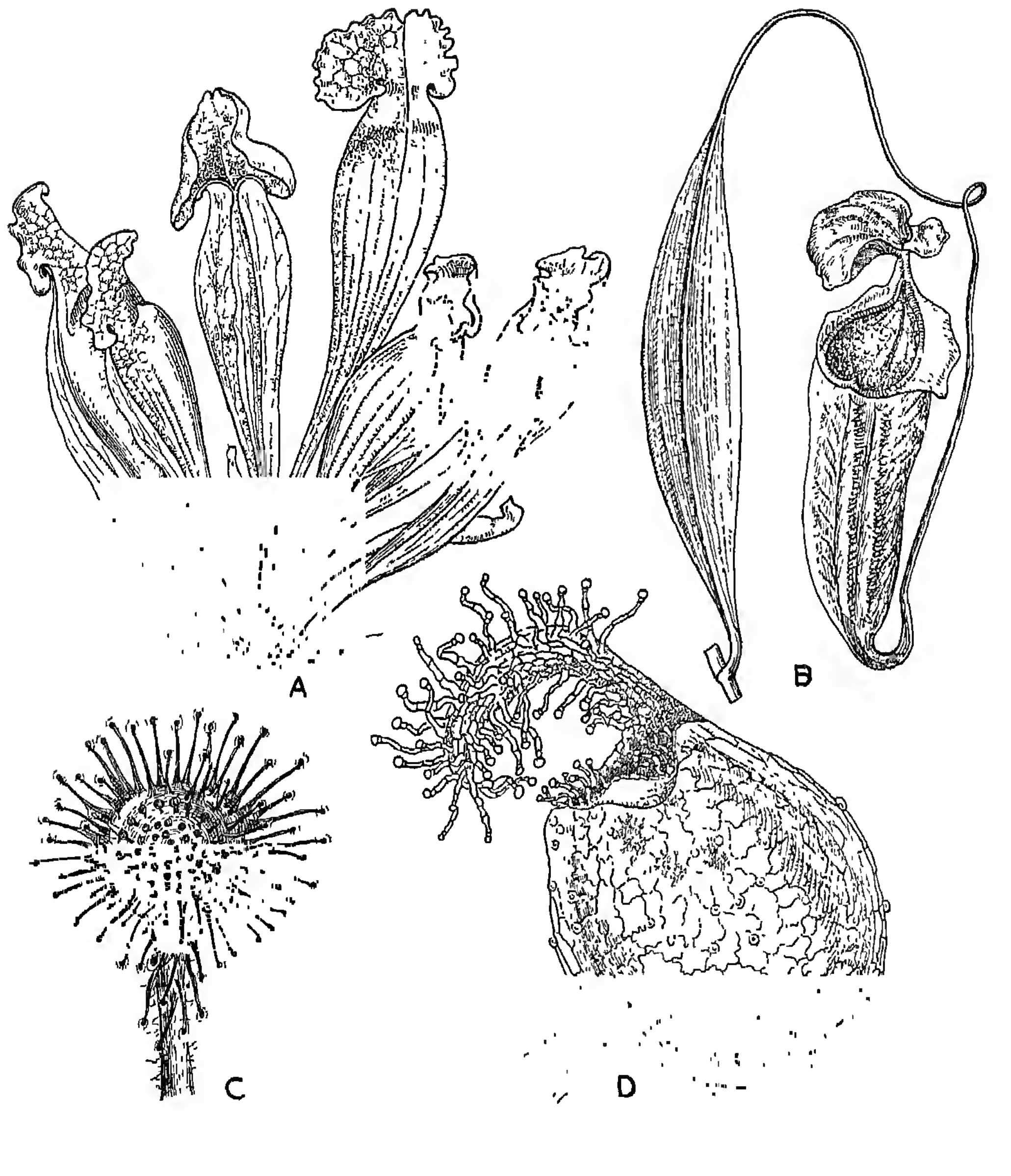

Fig. 13.4. **Curious leaves of insectivorous plants. A and B. Pitcher plants** (*Sarracenia* **and** *Nepenthes*). **C. Sundew** (*Drosera*). **D. Bladderwort** (*Utricularia*) Courtesy of the Department of Botany, University of Delhi,

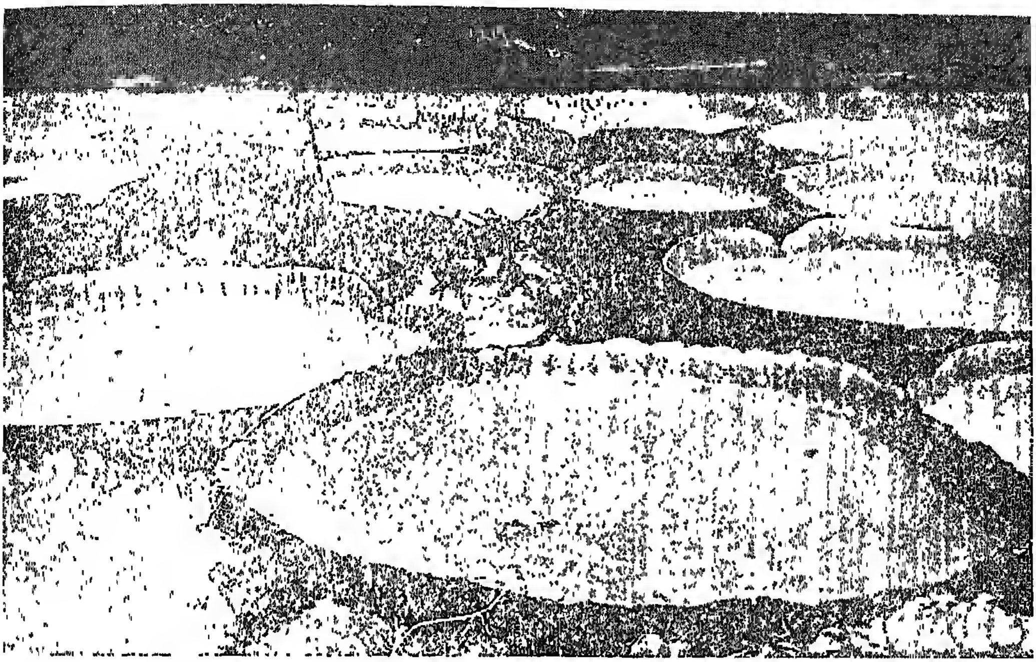

Fig. 13.5. The giant water lily (*Victoria regia*) with its large leaves having upturned margins. Courtesy of K. Subramanyam, Botanical Survey of India, Calcutta.

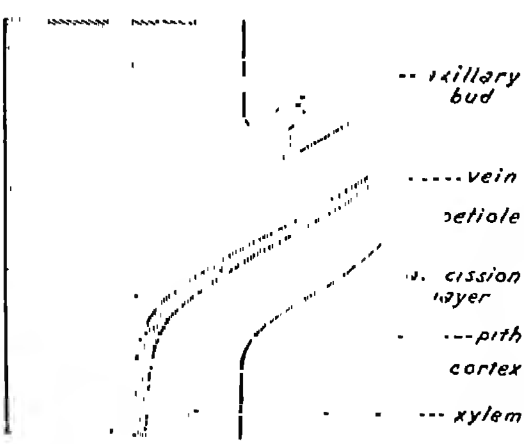

Fig. 13.6 Longitudinal section of a stem at the nodal region showing the abscission layer. After L J.F. Brimble, *Every-day Botany*, Macmillan & Company Ltd, London, 1953

Anatomy

The entire leaf generally appears green but if you examine a transverse section you would notice that chloroplasts are not found in all the cells. This is true of most of the cells of the upper and the lower epidermis which cover the two surfaces of the leaf. However, the epidermis has many minute openings called stomata (singular, stoma). Each stoma is bounded by two bean-shaped guard cells which differ from the rest of the epidermal cells in having chloroplasts (Fig. 13 7). In most plants the stomata are more numerous on the lower surface than on the upper. Quite often the outer walls of the epidermal cells are coated with a layer of cutin. This layer, called the cuticle, protects the leaf against desiccation by preventing an excessive loss of water.

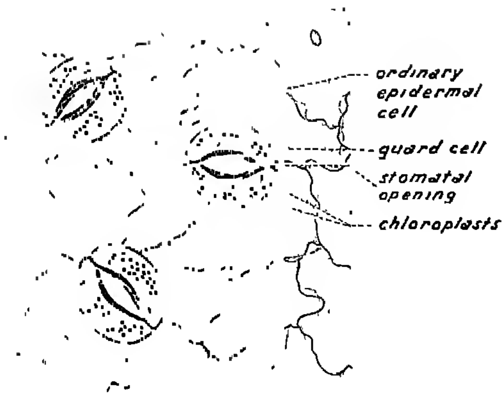

Fig. 13.7. The lower epidermal layer of a leaf. Note that only the guard cells contain chloroplasts. Courtesy of G.S Paliwal, Department of Botany, University of Delhi

Below the upper epidermis are seen one or more layers of closely packed columnar cells. Due to their arrangement like the poles of a fence or a palisade, they are known as **palisade cells** (Fig. 13 8) These cells are full of chloroplasts. Below the palisade layer there is a mass of loosely arranged cells with irregular shapes and fewer chloroplasts These cells enclose between them large air spaces This tissue is known as the **spongy parenchyma.** The palisade and spongy parenchyma together form the **mesophyll.** The intercellular spaces in the mesophyll form a good ventilating system which has contact with the external atmosphere through the stomata

The vascular bundles of the petiole continue into the midrib of the lamina A

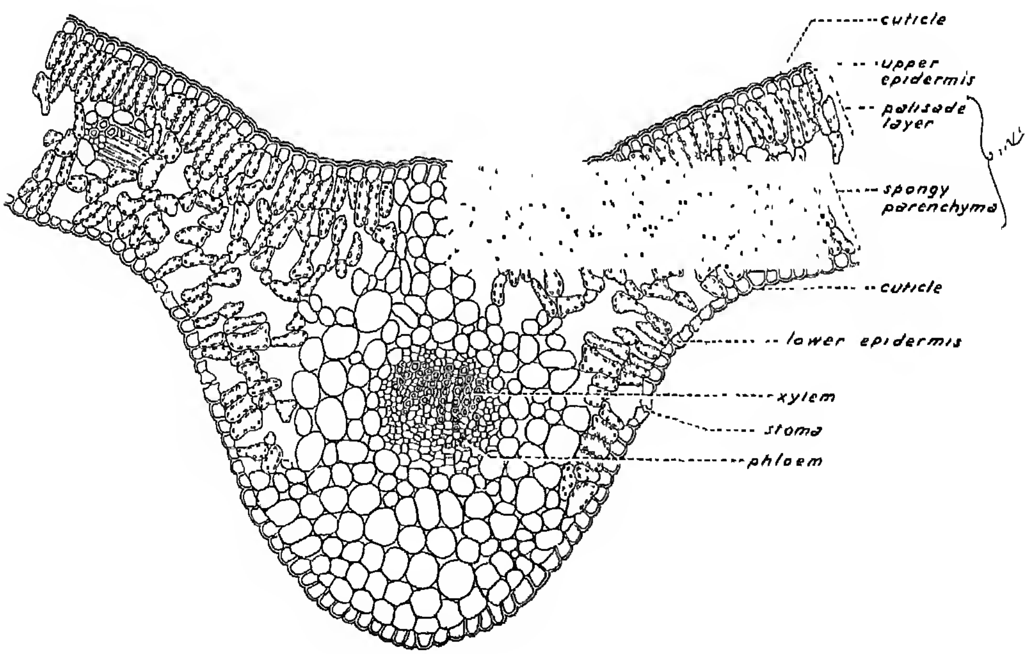

Fig. 13.8. Transverse section of a part of the leaf of a dicotyledon. Courtesy of the Department of Botany, University of Delhi.

large number of these veins branch and form a network (Fig. 13 9A) The finer branches of the network end in the midst of spongy parenchyma (Fig 13 9B). On examining a cross section of the lamina in which a vein has been cut at right angles, you will find that the xylem is situated towards the upper surface and the phloem towards the lower (Fig. 13 8)

Functions

The chief function of the leaf is the preparation of food for the plant through photosynthesis Through the open stomata of the leaf water vapour is constantly escaping to the outer atmosphere This process is known as transpiration and will be discussed in detail in Chapter 44 Another function performed by all living cells including those of the leaf is respiration resulting in the release of energy which is used for many synthetic processes in the plant

Uses

The leaves of many plants are used as vegetables Some familiar examples are cabbage, lettuce, spinach and several species of *Amaranthus* The leaves of certain plants such as Manila hemp (*Musa textilis*), and sisal (*Agave sisalana*) yield fibres Tea leaves are used to prepare a familiar beverage, while tobacco leaves are the basis for the cigar, cigarette and 'bidi' industries Peppermint is extracted from the leaves of *Mentha piperita*, digitalin (a remedy for heart troubles) from *Digitalis purpurea* and belladonna from *Atropa belladonna* A number of plants, such as coleus and croton, have variegated leaves and are used for ornamental purposes

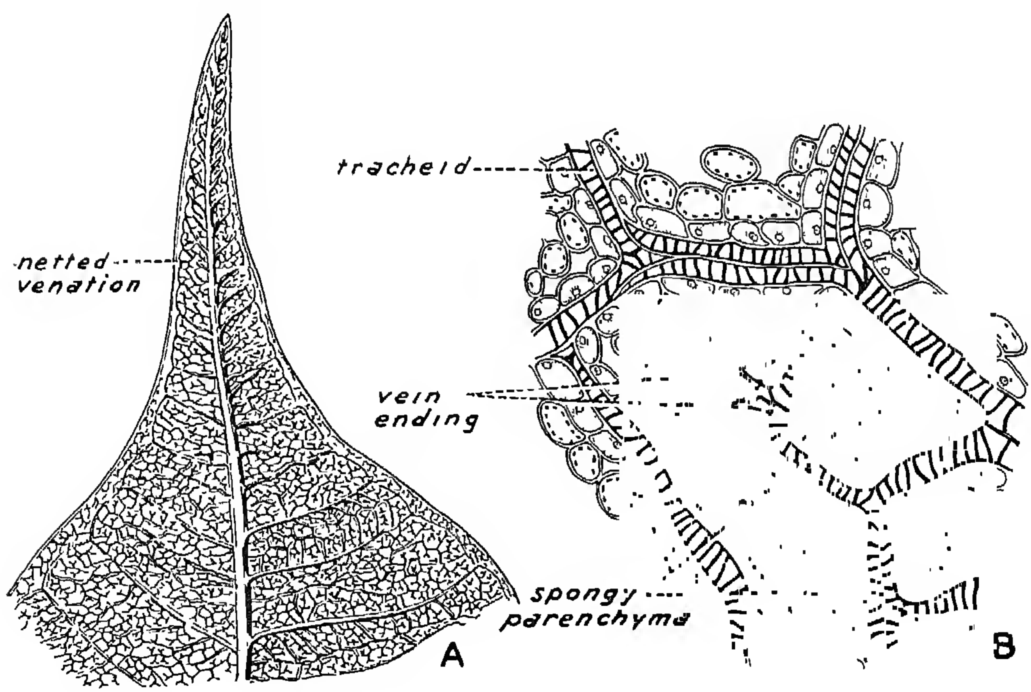

Fig. 13.9. Leaf veins. A. Part of a skeletonized leaf showing a network of veins. B. Part of a cleared leaf enlarged to show the vein-endings in the mesophyll. Courtesy of G.S. Paliwal, Department of Botany, University of Delhi.

SUMMARY

Leaves are broad, green, flattened structures whose chief function is the manufacture of food material. A typical leaf consists of a stalk (petiole), a lamina, and sometimes a pair of small leafy structures (stipules) at the base of the petiole. The lamina is richly supplied with veins which run parallel to each other in the monocotyledons but form a fine network in the dicotyledons. The shape, size, margin and pattern of venation of the leaves vary greatly. A simple leaf has a single blade or lamina whereas in compound leaves the lamina is subdivided into two or more units called leaflets.

The tissue between the lower and upper epidermal layers is called mesophyll. It consists of an upper palisade layer and a lower loosely arranged spongy tissue. The epidermis contains a large number of stomata through which the exchange of gases takes place.

Leaves of some plants are important as sources of food, drugs, beverages and fibres.

QUESTIONS

1. Explain the following.
   (a) The leaves of floating water plants have stomata only on their upper surface.
   (b) The leaves of submerged plants have no stomata on either surface.
   (c) It is easier to peel off the lower epidermis of a leaf than the upper.
2. Make a diagram of the transverse section of a leaf and label its parts. Why is it possible to see the vascular bundles in both transverse and longitudinal views?
3. Give the names of five plants whose leaves are used as food by man.
4. How can you distinguish a simple from a compound leaf? A compound leaf from a branch?
5. Describe some interesting forms of modified leaves.
6. What do you understand by (a) autumn colouration, (b) leaf-fall, (c) evergreen plants, (d) cuticle, (e) mesophyll?
7. Which type of venation, in your opinion, is more useful to the leaf: reticulate or parallel? Why?

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CHAPTER 14

The Flower

OF all plant parts, flowers are perhaps the most striking. To a layman the flower is an object of beauty, a source of inspiration, an excellent offering to the gods, or an invaluable aid in personal make-up. To a student of biology, however, the flower is more than just a thing of splendour. To him, it is the seat of sexual reproduction in a plant. It produces fruits and seeds, and the latter, as you know, germinate to give rise to new plants. Thus, flowers serve to continue the race. In this chapter you will study the structure of the flower and the functions performed by its various organs.

A flower may be regarded as a modified branch whose internodes have become condensed, bringing the nodes very close to one another. Further, instead of leaves it bears the floral organs. If you keep a young plant under continual observation for a few months, you will find that for sometime it produces only leaves and branches but later, some of the buds develop into flowers. The plant which bore green leaves now wears a new, colourful look. It is full of flowers. What makes a plant produce flowers is not fully understood. Biologists have found that the time of flowering of most plants is greatly influenced by environmental conditions like light and temperature.

Flowers differ greatly in the size, shape, colour and arrangement of their parts, yet most of them have a common structural plan. On one extreme there are the flowers of *Wolffia* which are microscopic, and on the other are those of *Rafflesia* which may be as much as one metre across (Figs 14.1 and 14.2)

Parts of a Flower

The gold mohur (*Delonix regia*) is a convenient, large flower to begin your study (Fig 14 3). The long stalk of the flower (pedicel) has an upper swollen region known as the **receptacle.** On this are borne the floral parts in circles or whorls. The outermost of these are the sepals which are collectively called the **calyx.** In a flower bud the calyx protects the developing inner parts (Fig 14 3 A). In an open flower the sepals are seen as small, drooping structures (Fig 14 3 B). They are red inside but green on the outside. Next come five large crimson petals collectively known as the **corolla** (L. *corolla*=small crown). This is the most conspicuous part of the flower. The flowers owe their beauty to the colour and form of the corolla. The long, thin structures occurring inside the corolla are the **stamens.** They are the male reproductive organs of the flower. In the gold mohur there are 10 stamens. Each stamen consists

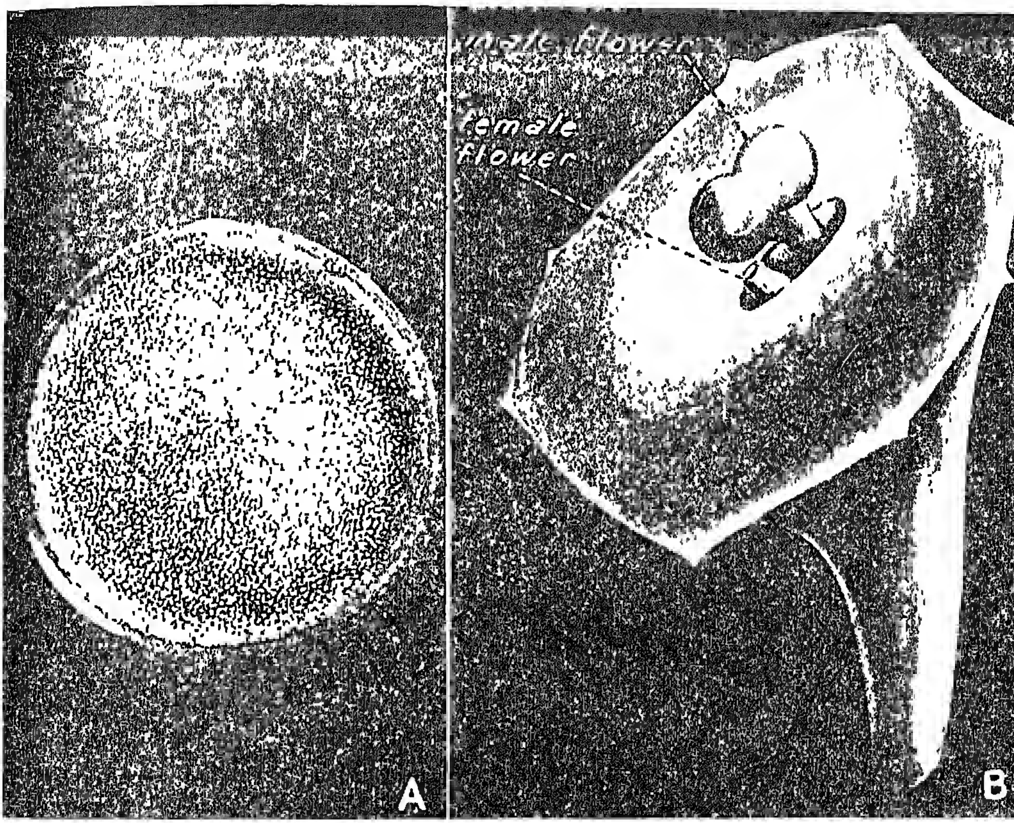

Fig. 14.1. *Wolffia*, **the smallest known flowering plant, possesses extremely minute flowers. A. A large group of plants in a petri dish (natural size). B. Single plant enlarged about 75 times to show the male and female flowers.** Courtesy of S C Maheshwari, Department of Botany, University of Delhi.

of a two-lobed sac (the **anther**) at the tip of a red, slender stalk known as the **filament** (Fig. 14.3 D) In a cross section each lobe of the anther shows two chambers An anther has, therefore, a total of four chambers (Fig. 14.3 I). Each chamber is filled with a fine, yellow powder formed of hundreds of tiny bodies called the **pollen grains**. Each pollen grain is protected by two coats of which the outer is thick and has a sculptured surface while the inner is thin and smooth. Under the microscope few things appear more beautiful than pollen grains When the anthers are ripe, they rupture and liberate the pollen as a fine dust The pollen grain produces the male gametes

Fig. 14.2. Flower of *Rafflesia* **It is the largest known flower.** Modified from B J D Meeuse, *The Story of Pollination*, The Ronald Press Company, New York 1961.

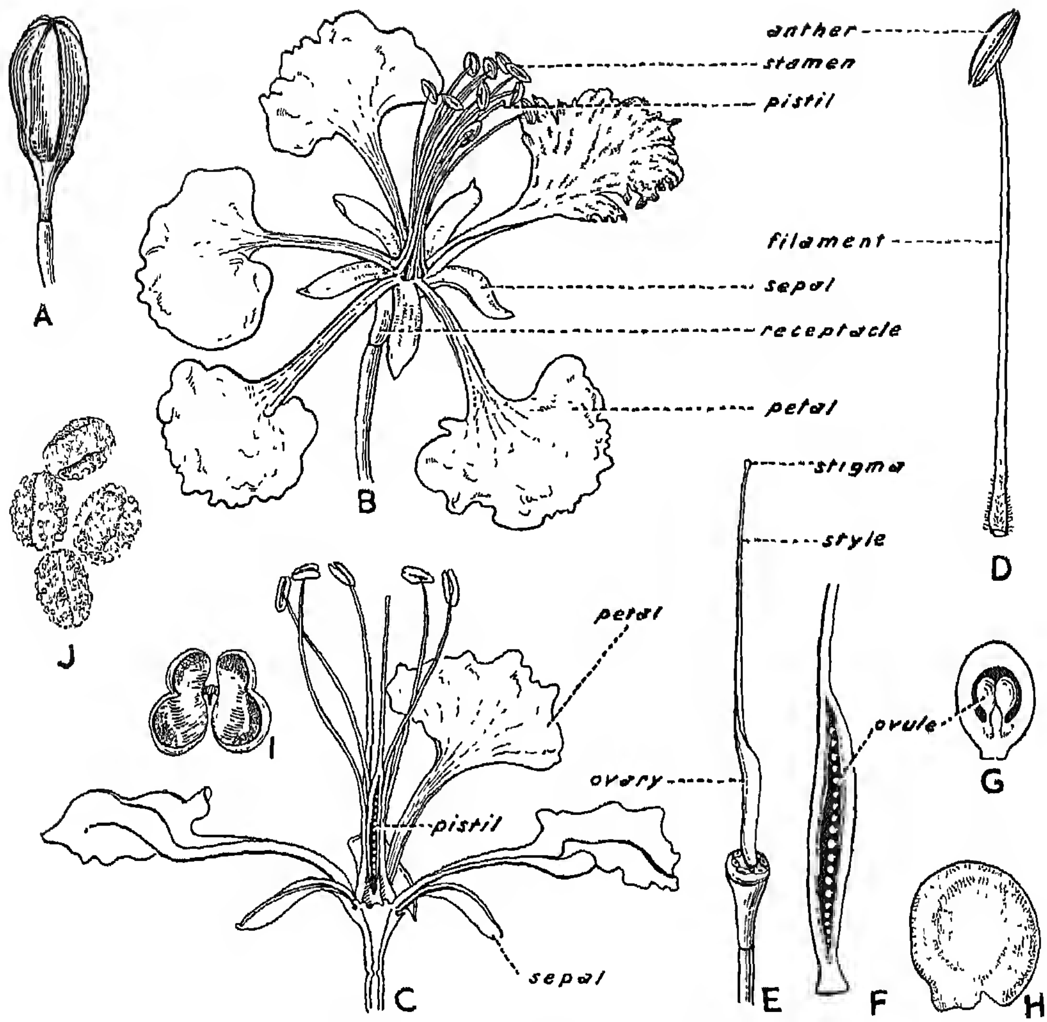

Fig. 14.3. Structure of gold mohur flower. A. Flower bud. B. Open flower. C. Longitudinal section of a flower. D. Stamen. E. Pistil. F. Longitudinal section of the ovary showing a row of ovules. G. Transverse section of the ovary. H. Ovule. I. Transverse section of the anther. J. Pollen grains. Courtesy of the Department of Botany, University of Delhi.

or sperms. This is why the stamens are called the male reproductive organs of the flower. You will study more about this aspect in a later chapter.

In the centre of the flower stands the female reproductive organ—the **pistil** (L. *pistillum*=pestle). Its enlarged, yellowish, basal part is the **ovary** (Fig. 14.3 C) The thread-like upper region, called the **style,** ends in a somewhat swollen and differently coloured tip, known as the **stigma** (Fig. 14.3 E). If you cut an ovary of the gold mohur lengthwise, you will see two rows of tiny, white pearly bodies along one of its

margins (Fig 14.3 F and G) These are the ovules, the future seeds (Fig. 14 3 H). Each ovule contains an egg

Be it a colourful and fragrant flower of lotus, 'champak' or lily, or a relatively inconspicuous flower of mango or wheat, its sole function is reproduction The pollen should be produced in abundance and it should somehow reach the stigmas Here the pollen grain germinates to form a **pollen tube.** This enters an ovule and bursts near the egg contained in the ovule. The egg and the sperm (the female and male sex cells or gametes respectively) fuse and fertilization is effected. Following fertilization the ovules develop into seeds and the ovaries mature into fruits

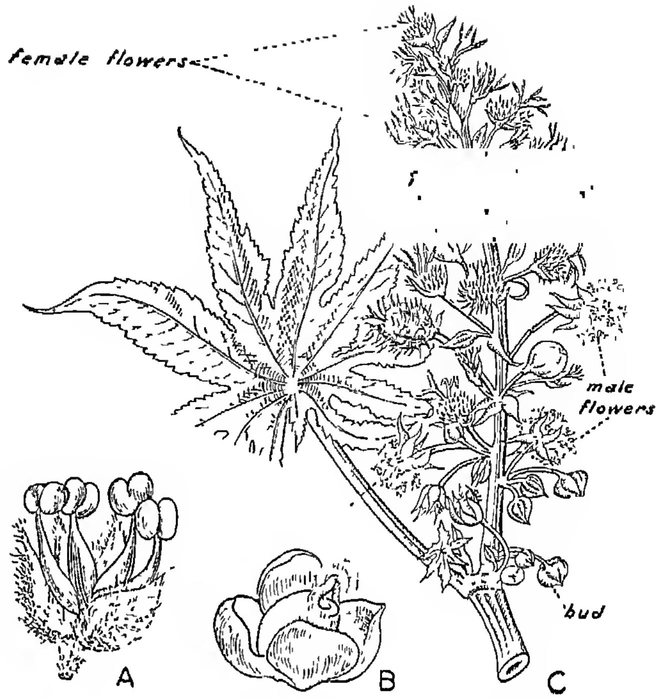

Fig. 14.4. Unisexual flowers. A and B. Staminate and pistillate flowers of mulberry (*Morus alba*). **C. Flowering branch of castor** (*Ricinus communis*) **bearing male and female flowers.** Courtesy of the Department of Botany, University of Delhi.

Variations in Flower Structure

A brief visit to a garden will convince you that there is a limitless variation in the types of flowers. Botanists have systematically studied and described all these types. It will perhaps require a lifetime to become familiar with all the types of flowers, but we shall introduce you to a few of the more common ones. It is an enjoyable hobby to study the different types of flowers closely with a hand lens

The gold mohur is an example of a **complete** flower, that is to say, it contains all the four types of floral organs—calyx, corolla, stamens and pistil. Not all flowers are complete, however. One or more of the floral organs may be lacking Such flowers are called **incomplete.**

Again, while the gold mohur has both stamens and pistil and is, therefore, a bisexual flower, other flowers may bear either stamens or pistil, but not both (Fig. 14 4). Such flowers are unisexual and may be male (**staminate**) or female (**pistillate**).

The position of the pistil also varies and is an important character in the identification of plants. In a flower like the gold mohur the sepals, petals and stamens are all attached below the ovary which is then said to be **superior.** However, if the sepals, petals and stamens are inserted above or on top of the ovary, the latter is then called **inferior** (Fig. 14.5)

In some plants the floral organs are so arranged that when one cuts through the

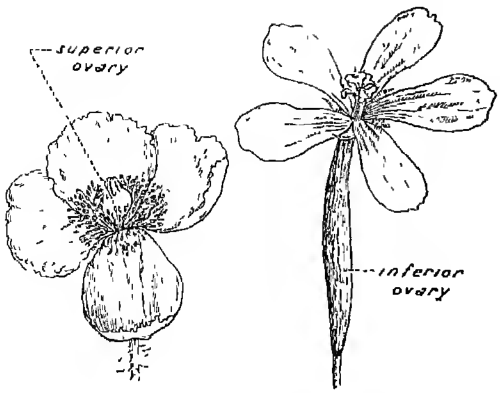

Fig. 14.5. Flowers with superior and inferior ovaries. Courtesy of the Department of Botany, University of Delhi

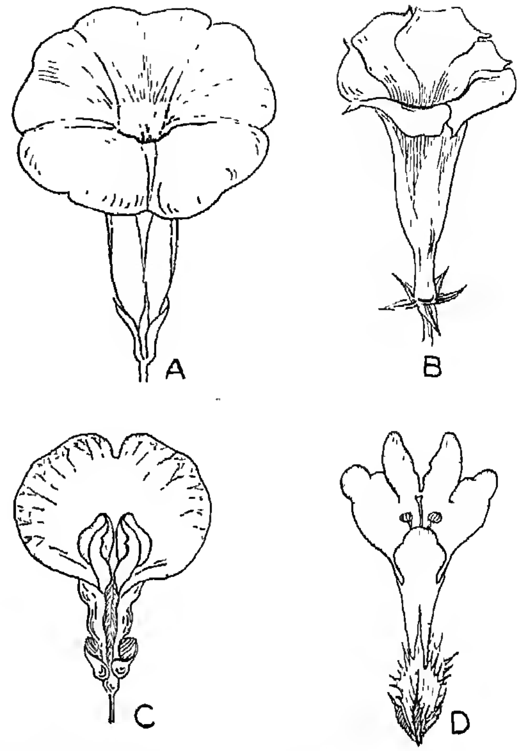

Fig. 14.6. Actinomorphic and zygomorphic flowers. A and B. Actinomorphic flowers of *Petunia* and *Thevetia* C and D. Zygomorphic flowers of *Pisum* and *Barleria*. Courtesy of the Department of Botany, University of Delhi

flower vertically in any plane passing through its centre, the two halves produced are exactly like each other Such flowers are called **regular** or **actinomorphic** (Fig. 14 6 A and B). On the other hand, in the flower of pea two equal halves can be obtained by cutting it in only one vertical plane Such flowers are said to be **irregular** or **zygomorphic** (Fig 14.6 C and D).

Further, the individual parts of flowers (sepals, petals, stamens and pistils) may vary greatly in their structure It is naturally impossible to consider them all, but a few examples will help you to observe the flowers more closely than you have ever done before. For the sake of convenience the variations in each floral part are shown separately (Figs 14.7, 14 8 and 14.9).

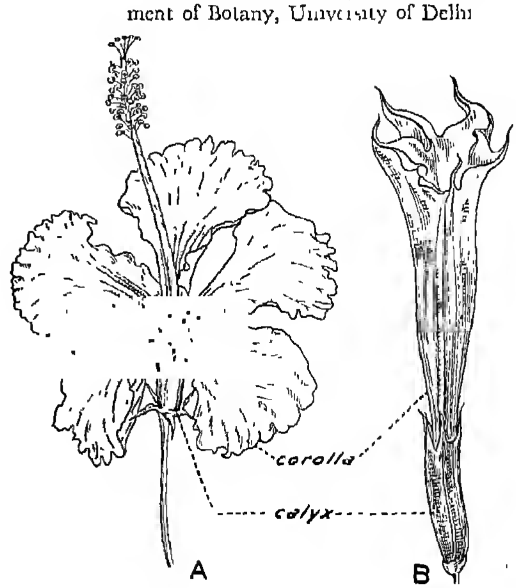

Fig. 14.7. The two common types of calyx and corolla. A. Free sepals and petals of China rose (*Hibiscus rosa-sinensis*). B. Fused sepals and petals of *Datura* forming calyx and corolla tubes. Courtesy of the Department of Botany, University of Delhi.

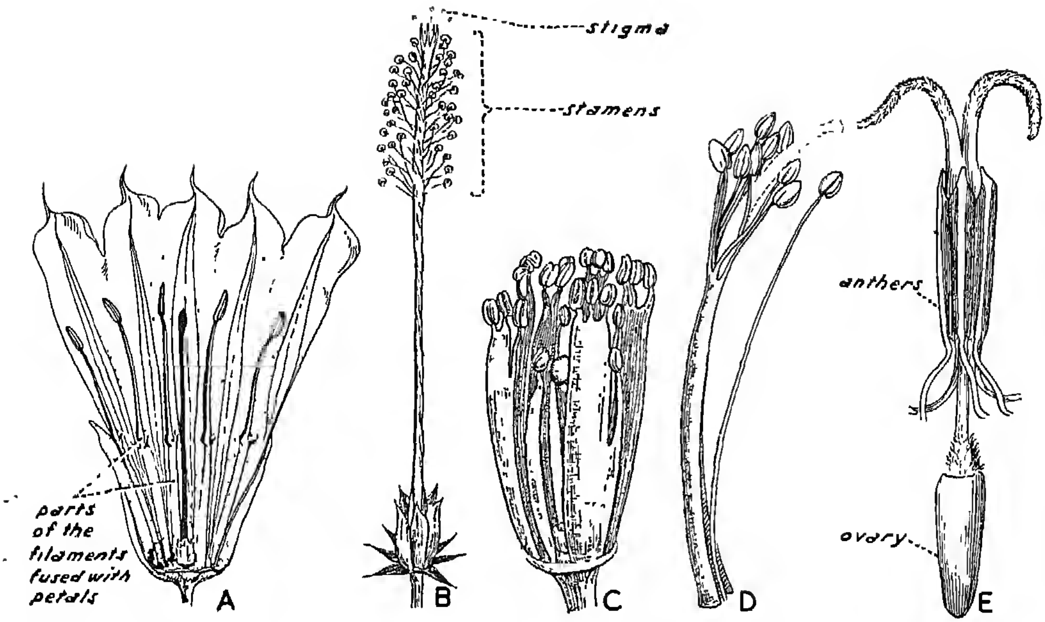

Fig. 14.8. Some common types of variations in the arrangement of stamens in flowers. A. *Petunia*, **the basal parts of the filaments are fused with the petals. B. China rose; the filaments are fused to form a hollow staminal tube which encloses the pistil. C.** *Citrus*, **the stamens are grouped into several bundles by the fusion of their filaments. D. Pea; nine of the ten stamens in a flower form a single bundle due to the fusion of their filaments, while the tenth stamen stands free. E. Sunflower; the anthers of the five stamens of a flower are fused with each other while their filaments are free.** Courtesy of the Department of Botany, University of Delhi.

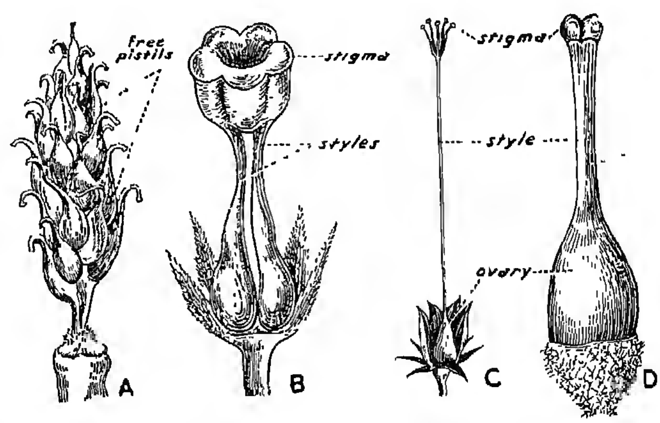

Fig. 14.9. Some common types of variations in the arrangement of pistils in flowers. A. 'Champak' (*Michelia champaca*), **the pistils are borne, free from each other, on the elongated axis of the flower. B. Milkweed** (*Calotropis*): **the terminal portions of the two pistils are fused into a common stigma while the styles and ovaries remain free. C. China rose** (*Hibiscus rosa-sinensis*), **the ovaries and styles of the five pistils are united while the stigmas remain distinct. D. Brinjal** (*Solanum melongena*); **the ovaries, styles and stigmas of both the pistils are completely fused. In such instances the number of pistils is usually indicated by the number of chambers in the ovary or the number of lobes of the stigma.** Courtesy of the Department of Botany, University of Delhi

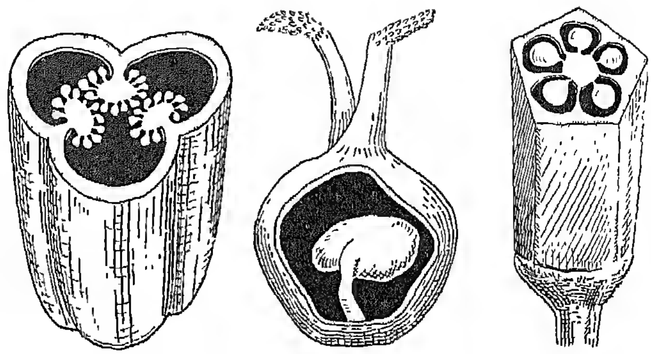

Fig. 14.10. Some common types of placentation. In the parietal as well as basal types the ovary is single-chambered. In the former type the ovules are borne near the wall of the ovary while in the basal type there is a single ovule attached at the base of the ovary. Courtesy of the Department of Botany, University of Delhi.

The fragrance of flowers is due to the presence of **essential oils** in special cells of the petals or other parts. The flower colours result from the presence of pigments called anthocyanins and carotenoids. Special glands called **nectaries** may occur at the base of petals. They secrete a sugary fluid, the **nectar,** which is greedily sought after by insects. They are guided to this by the fragrance and colour of the petals.

The part of the ovary bearing the ovules is called **placenta** and the arrangement of placentae in an ovary is termed **placentation.** In your study of the different kinds of flowers you will come across several types of placentation The more important types are shown in figure 14.10.

In the dicotyledons, the parts of a flower are usually arranged in whorls of four or five. In the monocotyledons, on the other hand, the parts are commonly arranged in whorls of three.

The flowers are sometimes borne singly at the ends of branches (terminal position) or in the axils of leaves (axillary position). More frequently, however, they occur in a group on special floral branches called **inflorescences** (Fig. 14.11). The 'sunflower' is actually not a single flower but a collection of a large number of tiny flowers or florets on a flat disc-like receptacle. The

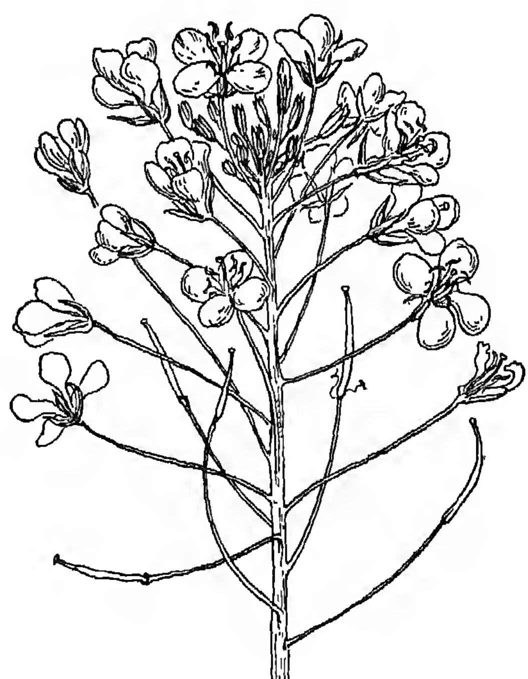

Fig. 14.11. Inflorescence of turnip (*Brassica campestris*). Courtesy of the Department of Botany, University of Delhi.

florets borne on the periphery of the disc (**ray florets**) are female while those in the centre (**disc florets**) are bisexual (Fig. 14 12)

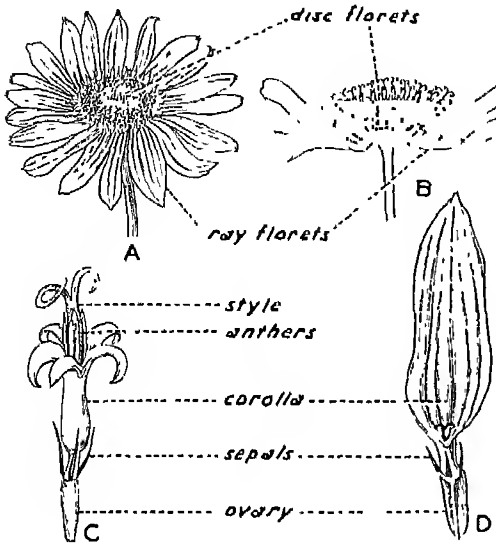

Fig. 14.12. Sunflower. A. The entire inflorescence (head). B. Longitudinal section of the inflorescence. C and D. The disc and the ray florets. Courtesy of the Department of Botany, University of Delhi.

Uses

The brilliant colours and varied shapes of flowers give us enjoyment and relaxation, and brighten our everyday life. Gardening is perhaps the most fascinating hobby. Some flowers have sweet fragrance and are the source of much wanted perfumes and flavouring materials. Perfumes of roses, jasmine and 'keora' (*Pandanus odoratissimus*) are in great demand in our country. Cut flowers are used for interior decoration.

Some flowers or flower buds such as those of 'samjna' (*Moringa*), 'kachnai' (*Bauhinia*), and banana are used as human food. Cloves, so often used as spice and in medicine, are the dried flower buds of the clove tree (*Eugenia caryophyllata*). The edible portion of cauliflower is an inflorescence which has become monstrous and sterile

Several colouring materials are derived from flowers. Saffron, so often used at weddings and other ceremonial occasions in our country, comes from the stigmas and styles of *Crocus sativus*. The petals of safflower (*Carthamus tinctorius*) and flame of the forest or 'dhak' (*Butea monosperma*) yield orange coloured dyes. A similar dye is obtained from the tube-like corolla of 'harshingar' (*Nyctanthes arbor-tristis*), and it is said that the garments of Lord Krishna used to be dyed with this.

SUMMARY

The flower is the seat of sexual reproduction in plants. Its main function is the formation of seeds. A complete flower has sepals, petals, stamens, and pistils.

Typically a pistil has three parts: stigma, style and ovary. The stigma receives the pollen grains. The pollen tubes grow through the style into the ovary which

contains the ovules The ovules are borne on the placenta.

The anther contains the pollen grains and is borne on a stalk called the filament The sepals and petals protect the inner parts in the bud and may also serve to attract insects because of their colour and smell

There is a wide variation in the number, size and form of the various parts of a flower. Quite often one or more types of organs may be completely absent from a flower

Flowers are not only objects of enjoyment and relaxation but are also the source of several important products like perfumes, spices and dyes

QUESTIONS

1. Which flower would you recommend as the national flower of India? Why?
2. How will you determine whether the colours of flowers help in attracting insects or not?
3. How does reproduction in an angiosperm differ from that in an animal, say a cow?
4. Explain the following terms: pistil, incomplete flower, zygomorphic flower, and staminate flower.
5. List some useful products obtained from flowers.
6. What is the difference between (a) flower and inflorescence, (b) superior and inferior ovaries?
7. How can you distinguish the flowers of monocotyledons from those of dicotyledons?
8. Which plant has the smallest flower, and which has the largest?
9. In what way is it advantageous for a plant to have its flowers clustered into an inflorescence?

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CHAPTER 15

Pollination and Fertilization

DURING a visit to a garden or a field of brinjals, water melons or cucumbers you must have seen bees and butterflies fluttering up and down and perching upon some flower every now and then. If you are a little more observant, you will discover clumps of a yellow material sticking to the legs of these animals. This yellow powder is the pollen, and as the insect visits the flower in search of food it is unintentionally doing it a good turn by taking care of a very important process in the life of the plant.

You will recall that in a flower we find one or more pistils surrounded by the stamens The upper part of each stamen, called the anther, produces a large number of tiny pollen grains forming a fine powder Most often this powder is yellow or orange in colour. Inside the lower part of the pistil (ovary) there are the ovules The ovary matures into a fruit, and the ovules into seeds. However, before this can happen it is necessary that in some way or the other the pollen grains should get deposited on the stigma of the pistil. Here they germinate to form long tubes which grow down the style and bring about fertilization of the ovules.

POLLINATION

The transference of the pollen to the stigma is called **pollination.** It is, as it were, a green signal for the ovaries and ovules to start transforming themselves into fruits and seeds. It is an essential process in the chain of events leading to the formation of seeds which, as you know, are essential for the perpetuation of most kinds of plants.

Most flowers have stamens as well as the pistil. You would naturally expect that pollen from a flower would pollinate its own pistil. This is no doubt true of some of our common crop plants, e g. tobacco, wheat and rice. However, in a majority of flowers the pistils cannot or do not accept the pollen of the same plant. They have instead to be pollinated by pollen from other plants of the same species.

In animals this kind of a union between the male and the female presents no special difficulties. As Grant puts it: 'Impelled by an urge to mate, the male and female swim, crawl, walk or fly until they find each other'. On the other hand, the union of two flowering plants, anchored by their roots to separate spots on the ground, presents a problem which can be solved only

by the intervention of a third party. The pollen of one plant must be carried to the pistil of the other by an external agent such as wind, water current, an insect or some other animal. Obviously these agencies cannot be ordered by the plant to work at its will; things must be so arranged that the agents inevitably contact the plant and carry its pollen As you will learn further, this is one of the most fascinating examples of the close relationship between plants and animals

Although mankind has lived among flowers for many centuries, to most people they were merely objects of charm and beauty from which they derived inspiration and pleasure. The biological function of the flower and the significance of pollination were realised only in the 17th century by a German botanist Camerarius In very ancient times (800 B.C.) people in Arabia, Syria, Babylon and Egypt already had some working knowledge of pollination There existed a practice of shaking the male flowers of the date palm over the female plants to ensure a good crop of dates. In some places this practice became a regular ceremony in which the head priest used to lead a procession of people carrying bunches of male flowers to be shaken over the fruit-bearing date palms It appears that the ancient Hindus were also aware of sexuality in plants at least in the 'keora' (*Pandanus odoratissimus*), for they spoke of pairs of these plants as 'ketakidwayama' (that is, male and female) They also discussed something about the method of seed production in plants However, all these ideas were lost or forgotten and they had to be rediscovered by systematic experiments of several biologists in the 16th and 17th centuries.

Self- and Cross-Pollination

It should be clearly understood that the term pollination is applied only to the process of transference of pollen from the anthers to the stigma This is expected to be followed by fertilization. The transference of pollen within the same flower or between different flowers of the same plant is called **self-pollination** (Fig. 15.1). When the pollen is carried from the flowers of one plant to those of another plant the process is termed **cross-pollination** (Fig. 15.1) Self-pollinated flowers are mostly

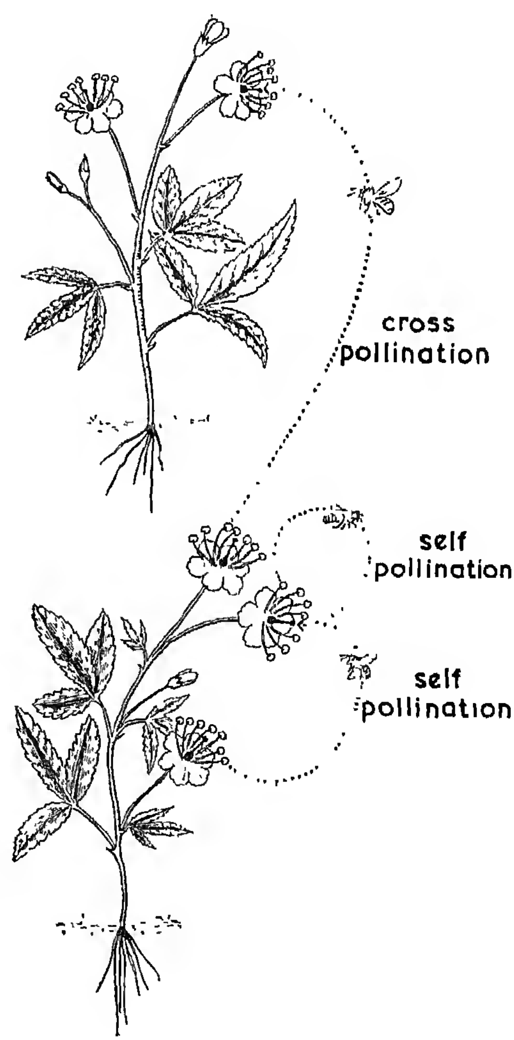

Fig. 15.1. Self- and cross-pollination. Courtesy of the Department of Botany, University of Delhi.

bisexual and do not require the help of an external agency for their pollination. Among these are wheat, oats, barley, tobacco, peas and others. Here the stigmas usually become covered with the flower's own pollen before the petals unfold. Although it seems more convenient for the plant to have its own pollen landing on the stigmas, 'Nature seems to abhor self-pollination' since it makes the progeny weaker and less fertile. In the progeny of cross-pollinated plants, on the other hand, there is a mixing up of characters from two different parents. This bestows on the offspring certain advantages for survival

Agencies of Pollination

A large proportion of flowering plants are pollinated by insects. The insects involved are chiefly butterflies, moths and bees (Fig 15 2) Horticulturists therefore advise the establishment of beehives in orchards to ensure cross-pollination in order that the fruit crop may be large and of a superior

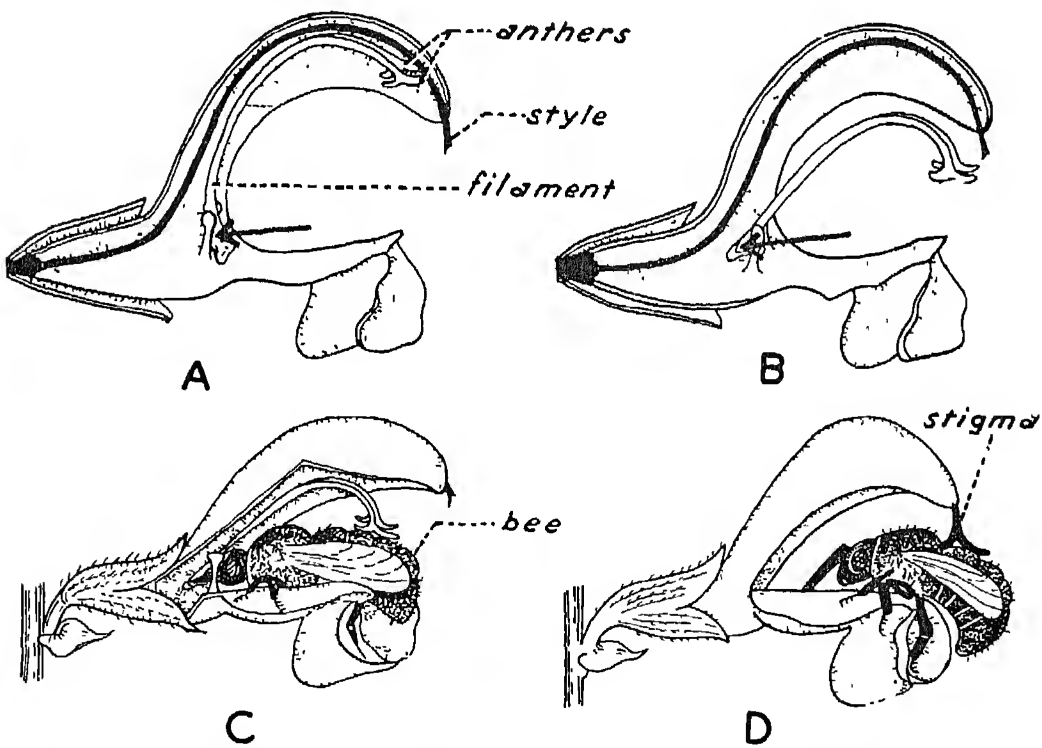

Fig. 15.2. Pollination in *Salvia*. The male and female parts of the flower are so constructed that a bee entering the flower in search of food automatically brings about pollination. A. Longitudinal section of a flower; the arrow points to the plate formed by the fusion of the bases of the two stamens. B. Pressure against the plate (indicated by arrow) causes the anthers to tip forward. C. The bee pushes against the plate, and the anthers tip forward and deposit the pollen on the back of the bee. D. Bee visits an older flower, the stigma has now grown downward, the lobes open, and the bee brushes against the stigma which now receives the pollen. From C.L. Wilson and W.E. Loomis ,*Botany*, Holt, Rinehart and Winston, New York, 1962.

quality. You might wonder as to what the insects seek when they visit flowers They obtain food from the flowers in the form of the pollen itself or the nectar secreted by the flower. The nectar collected by bees is mixed with saliva, poured out into the compartments of the honeycomb and then evaporated to a syrupy consistency by the fanning of the worker bees Sometimes the flower serves as a place for the insect to lay its eggs.

The insect is guided to a flower by colour or fragrance That is why insect-pollinated flowers are brightly coloured, or highly scented or both. Except where pollen-eating insects are involved, such flowers produce relatively less pollen than those which are wind-pollinated. Ignorance of the role of insects in pollination has sometimes led to serious difficulties when new plants are introduced into a locality. The story of the Smyrna fig (*Ficus carica*) is a well-known example of this Tempted by its delicious fruits, some fruit growers in California (USA) introduced this plant from Turkey. Although the trees grew well, the fruits dropped off before reaching maturity and the fruit growers suffered a great loss Then somebody discovered that a small insect was necessary for its pollination. As

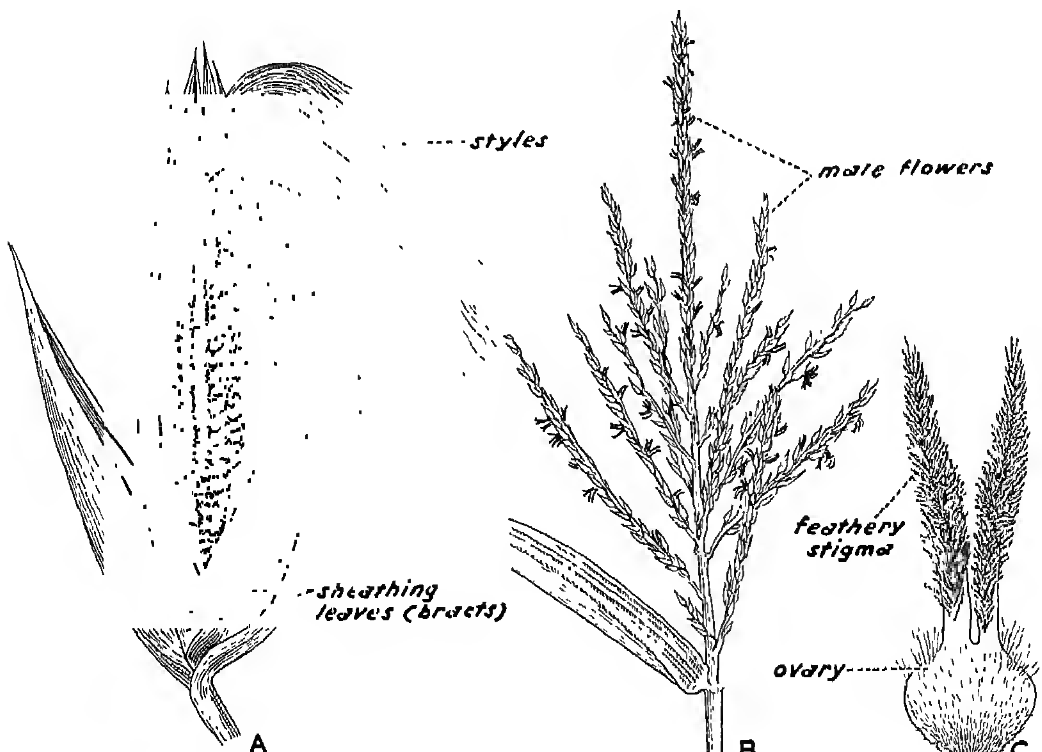

Fig. 15.3. Two examples of flowers pollinated by wind. A and B. Unisexual flowers of maize. The female flowers are borne in an 'ear', enclosed by sheathing leaves. The styles ('silk') of the flowers are freely exposed and catch any pollen in the air. In the male flowers the mature anthers dangle freely and allow their pollen to be carried by wind. C. Pistil of a grass, the feathery or brush-like stigmas project from the flower and catch pollen from the air. Courtesy of the Department of Botany, University of Delhi.

it did not occur naturally in California, it was introduced by man's efforts and after a few years the fig trees began to bear fruit.

Besides insects other agents like wind, birds and water are also effective in bringing about cross-pollination (Figs 15 3 to 15 5)

It should be realized, however, that there is no absolute specificity in the agency of pollination of a given plant species. Thus, a wind-pollinated flower may also be visited

Fig. 15.4. The female sunbird sipping nectar from the flowers of *Aloe* Incidentally she transfers pollen from one flower to another. Courtesy of Horizon de France, Paris

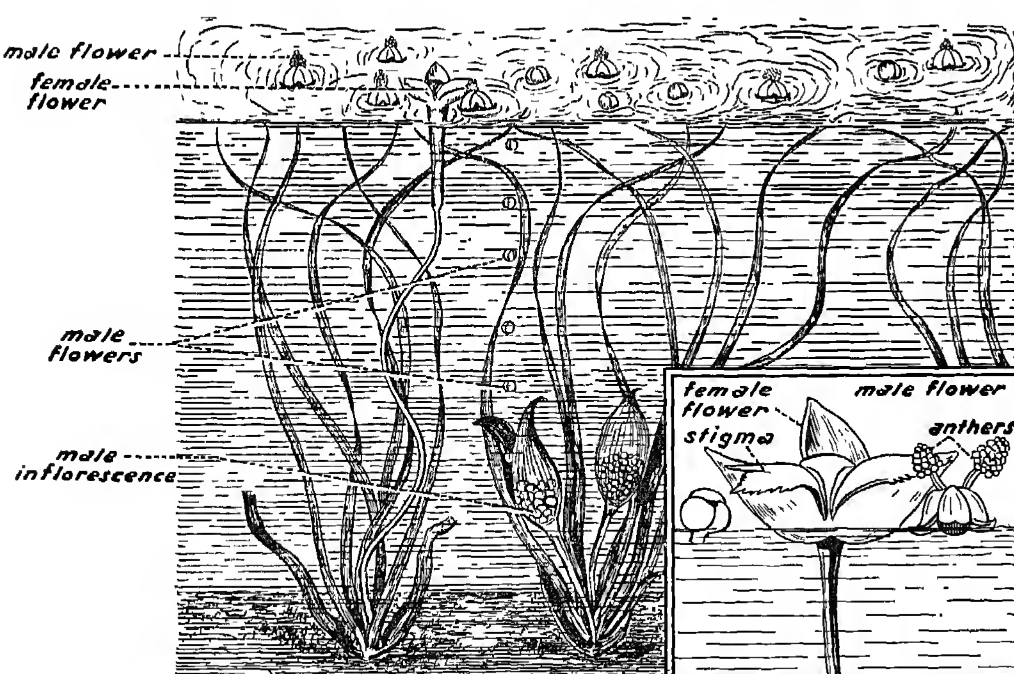

Fig. 15.5. Pollination in *Vallisneria* by water. The female flowers are borne at the apices of long twisted stalks and come to lie on the surface of the water. The male flowers are small and are borne at the base of the plant. When mature, they break off from the plant and rise to the surface. Each male flower has boat-shaped petals which act as floats, keeping the stamens erect above the water. The pollen boats eventually bump into the female flowers. The jolt of the collision causes the clump of pollen to be shot to the stigmas. After W.H Brown, *The Plant Kingdom: A Textbook of General Botany*, Ginn and Company, Boston, 1935

occasionally by a flying insect. Alternatively, a flower normally pollinated by insects may occasionally receive some pollen grains which a gust of wind may have carried from another flower.

Thus we find that although plants cannot move bodily to achieve a union of the male and the female gametes, agencies like wind, water, insects and other animals incidentally help them do so. We shall now study the events that follow this physical transference of the pollen from the anthers to the stigmas

Wind-Borne Pollen and Allergy

During the flowering periods of wind-pollinated plants, there is a high concentration of pollen in the air. Strangely enough, many people are **allergic** to this impurity of air, that is to say, when the pollen is inhaled, it produces respiratory diseases such as hay fever and asthma. Corresponding to the period of maximum liberation of pollen, the patient shows a recurrence of the disease every year. In surveys of atmospheric pollen conducted in Delhi, Jaipur and some other cities, the pollen of several plants (Fig 15.6) was found to be abundant in the air Clinical tests performed in hospitals have confirmed that many cases of respiratory diseases could be traced to inhalation of pollen with the air

FERTILIZATION

At the time of pollination the stigma is usually covered over with a sticky secretion containing sugar, organic acids and other substances This secretion forms a suitable medium for the germination of the pollen grains.

Before looking into the events that follow pollination let us have a closer look at the ovules in which the process of fertilization actually takes place Each ovule is attached to the ovary by means of a stalk. The body of the ovule, called the **nucellus,** has one or two envelopes or **integuments** which cover it completely except at the tip where a small pore or **micropyle** (Gk. *micros*=small, *pyle*=gate) is left (Fig. 15.7) The nucellus contains the **female gametophyte** or **embryo sac** which has eight nuclei (Fig 15.8). One of the three nuclei towards the micropyle is organized into a large female gamete or egg The other two cells, one on each side are the 'helpers' or **synergids** (Gk *synergos*=co-operator). The three nuclei towards the stalk of the ovule form another

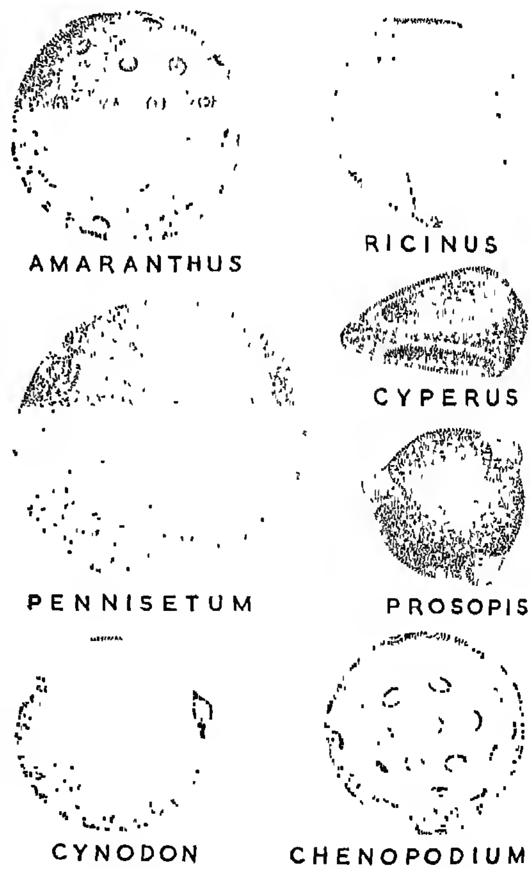

Fig. 15.6. Some pollen grains which cause respiratory diseases. Courtesy of the Department of Botany, University of Delhi.

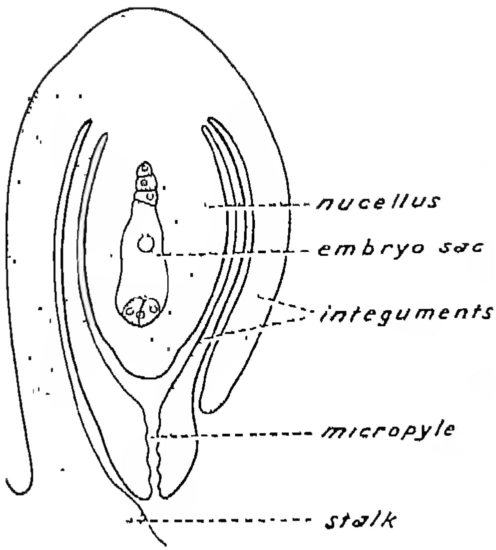

Fig. 15.7. Longitudinal section of an ovule containing an embryo sac. Courtesy of N.N. Bhandari, Department of Botany, University of Delhi

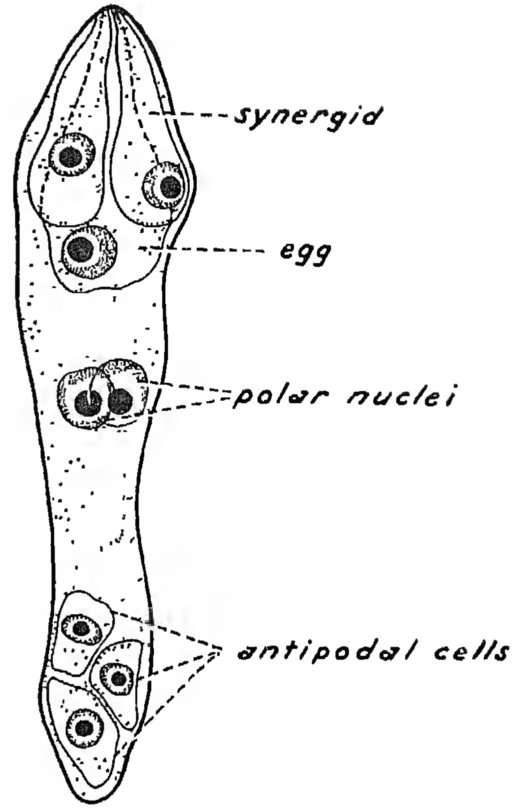

Fig. 15.8. The mature female gametophyte or embryo sac. Courtesy of S. B Sethi, Department of Botany, University of Delhi

set of three cells called the **antipodals** (Gk. *anti*=against; *pous*=foot). The remaining two nuclei lie very close to each other near the centre of the sac. Since they are derived one from each end (pole) of the sac they are called **polar nuclei**. Just before fertilization the two polar nuclei may fuse to form a single nucleus called the **secondary nucleus**.

After being lodged on the stigma the pollen grains swell, their outer walls burst, and the inner walls come out in the form of small protuberances. Gradually, each protuberance elongates and forms a pollen tube (Fig. 15.9) which grows through the style and reaches the ovary. The tube continues its growth along the inner wall of the ovary until the tip comes in close proximity to the ovule. It penetrates the ovule through the

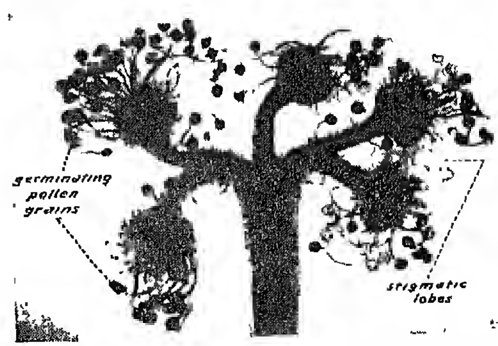

Fig. 15.9. The stigma of *Pavonia* **showing a large number of germinating pollen grains.** Courtesy of M M. Johri, Department of Botany, University of Delhi.

micropyle, continues its passage through the nucellus, and finally enters the embryo sac (Fig. 15.10).

The pollen tube carries some cytoplasm, two male gametes and an additional nucleus called the **tube nucleus.** This was so named because it was believed to direct the growth of the pollen tube in some way.

After entering the embryo sac, the tip of the pollen tube bursts and discharges its contents. One of the male gametes fuses with the egg, forming the **zygote.** The other male gamete fuses with the secondary nucleus. The fusion product is called the **primary endosperm nucleus,** since it is this which later forms the nutritive tissue known as **endosperm.** You would note that here we have a case of **double fertilization:** one male gamete fertilizing the egg and the other fertilizing the secondary nucleus.

The process of fertilization is essential for the ovules to develop into viable seeds and for the ovary to grow into a fruit After fertilization the tip of the pollen tube shrinks and is absorbed in the embryo sac. Simultaneously there is a withering of the stigma, style, stamens and corolla. The calyx may also fall off but in some fruits it persists so as to enclose the fruit

The fertilized embryo sac enlarges a good deal and in due course the zygote produces the embryo. Almost simultaneously the primary endosperm nucleus divides repeatedly to form the endosperm tissue which nourishes the developing embryo. The integuments become the seed coats (Fig. 15.11).

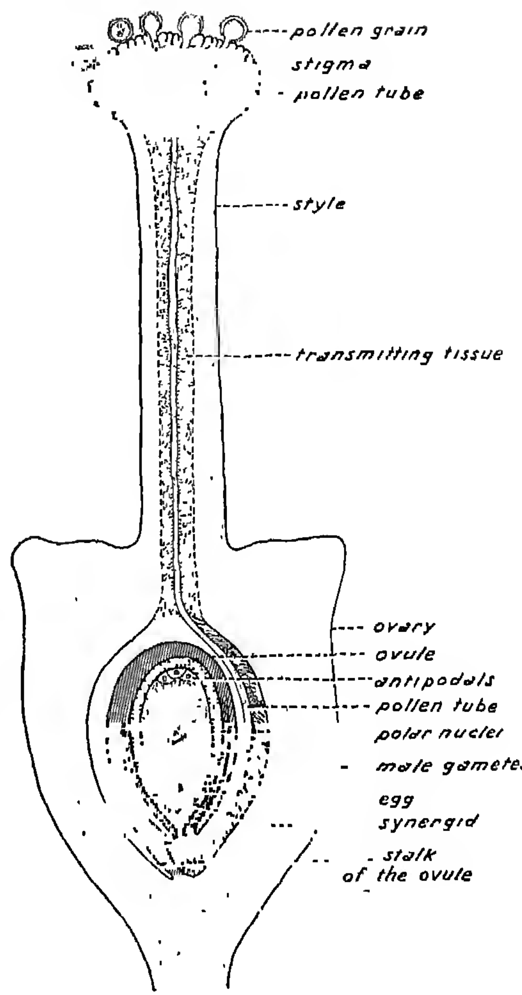

Fig. 15.10. Diagram showing the path of pollen tubes in the pistil. The pollen germinates on the stigma and the pollen tube grows down the style into the ovary. It travels along the inner side of the ovary wall and enters the ovule through the micropyle. Note one of the male gametes near the egg and the other in contact with the polar nuclei. Courtesy of M M. Johri, Department of Botany, University of Delhi.

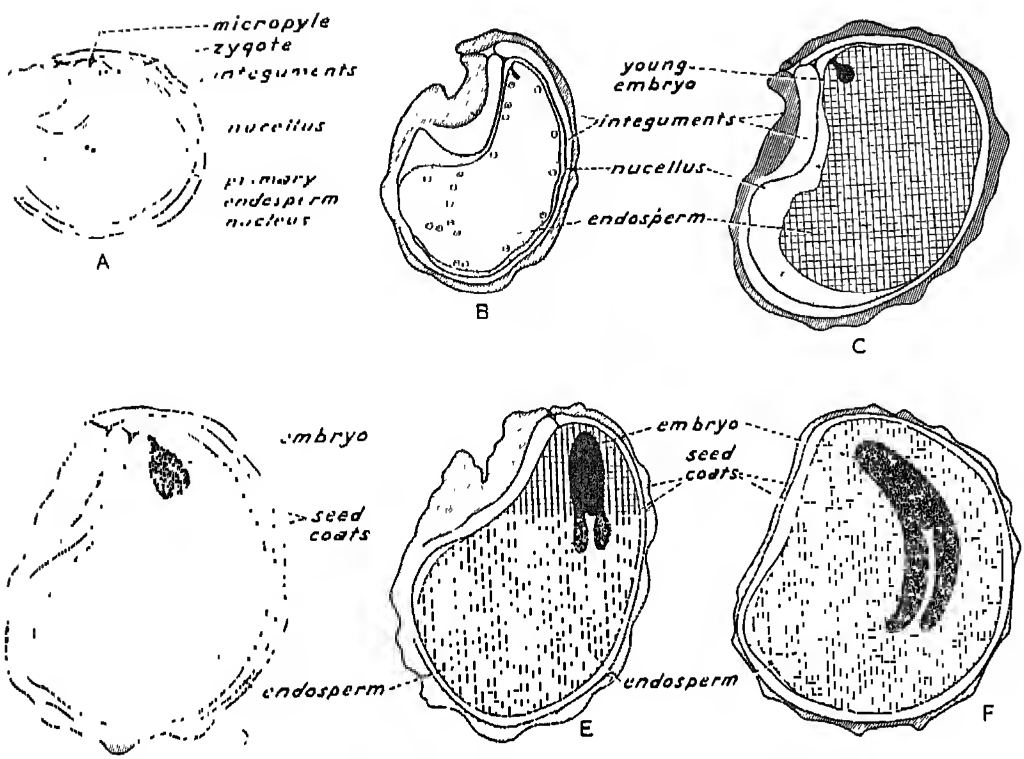

Fig. 15.11. From ovule to seed—a diagrammatic representation of the changes undergone by an ovule in the process of becoming a seed. Courtesy of M.M Johri, Department of Botany, University of Delhi

SUMMARY

Pollination is the transference of pollen from the anthers to the stigma. Such transference within the same flower or between different flowers of the same plant is called self-pollination. When pollen is carried from the flowers of one plant to those of another, the process is termed cross-pollination. Pollination is essential for the production of fruits and seeds.

In cross-pollinated plants the pollen of one plant is carried to the pistil of the other by external agents such as wind, water

currents and insects or other animals. Plants show suitable adaptations for making use of these pollinating agencies. Inhalation of the air-borne pollen of certain plants may produce respiratory disorders.

After becoming lodged on the stigma, the pollen grains germinate to form long tubes which grow down the style and enter the ovules through their micropyles. The pollen tubes carry two male gametes, a tube nucleus and cytoplasm

At this time the ovules generally contain mature embryo sacs. Each embryo sac contains an egg apparatus (egg and two synergids), three antipodal cells and a secondary nucleus.

After entering the embryo sac, the tip of the pollen tube bursts and releases the two sperms. One of these fuses with the egg forming a zygote, while the other unites with the secondary nucleus to give rise to the primary endosperm nucleus The zygote develops into an embryo, whereas the primary endosperm nucleus gives rise to the nutritive tissue called endosperm.

The stigma, style, stamens, petals and sepals all wither and fall off. The ovary matures into a fruit, and the ovules into seeds

QUESTIONS

1. How can you determine whether a plant is self- or cross-pollinated?
2. Devise an experiment to determine which colours are best perceived by a particular insect.
3. A botanist was consulted to decide whether a given sample of honey was genuine. In what way do you think he can be of help in this matter?
4. What do you understand by double fertilization?
5. Pea fruits sometimes contain very small underdeveloped seeds. Can you explain why they did not grow to the full size?

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CHAPTER 16

The Seed

SEEDS are the matured ovules. As mentioned in Chapter 15 their formation depends upon pollination and fertilization. Briefly, the events leading to the formation of seeds are as follows. The pollen grains germinate on the stigma, the pollen tubes grow down the style and enter the ovules. One of the male gametes from a tube fuses with the egg forming the zygote while the other fuses with the secondary nucleus. The zygote undergoes repeated divisions and finally forms the embryo or the young plant. The primary endosperm nucleus also divides many times to produce the nutritive endosperm tissue. This tissue nourishes the embryo during its development and at the time of germination. The seeds of many plants such as the bean have no endosperm when mature. In such types it is completely absorbed by the developing embryo. While these changes are taking place, the integuments of the ovule change into the seed coats. Let us now consider the structure of some common seeds in more detail.

Structure of Seeds

Bean. Examine a bean seed after soaking it in water overnight (Fig. 16.1). On the concave side it shows a scar where

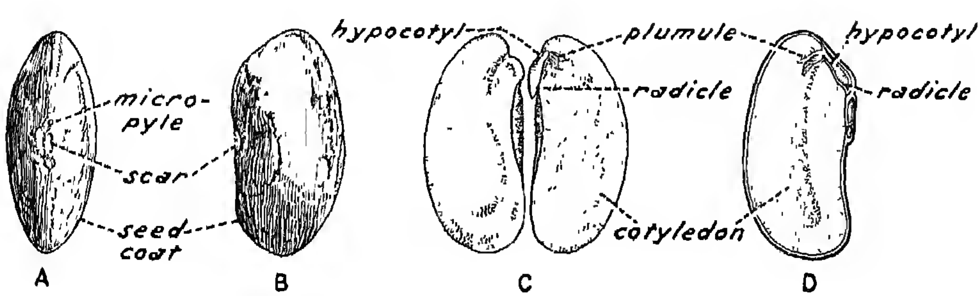

Fig. 16.1. Structure of bean seed. A and B. Front and side views of the seed. C. The testa has been removed and the two cotyledons spread apart to show the radicle and plumule. D. Section of the seed parallel to the flat surface. Courtesy of the Department of Botany, University of Delhi.

it was attached to the fruit. Below the scar is a small pore, the micropyle, through which the pollen tube entered the ovule (Fig. 16.1 A and B). Depending on the variety of bean, the seed coat may be white, light- or dark-brown and is generally smooth. On removing the seed coat you see the large, kidney-shaped cotyledons which are closely appressed to each other. When these are separated, a curved structure can be seen sticking to the inner side at the upper end (Fig. 16.1 C). This consists of two parts—the future root or radicle and the future shoot or plumule. The region between these two organs is known as the **hypocotyl.** The embryo of the bean, as indeed of all dicotyledons, consists of a radicle, a plumule, and two cotyledons. In this instance (bean) the cotyledons contain abundant food reserves in the form of proteins and starch which are utilized during germination. The mature seeds do not have any endosperm left in them and are, therefore, called **non-endospermic.**

Castor. The seed of castor is quite different from the bean. At its base is a soft, spongy structure, the **caruncle** (Fig. 16.2 A). The seed coat or **testa** is hard and brittle. It is mottled golden, dark-brown, or even black. The white, soft structure seen after removing the seed coat is the endosperm (Fig. 16.2 B). It contains abundant food reserves chiefly in the form of fats. In the centre of the endosperm, extending to almost its entire length and breadth, is the embryo (Fig. 16.2 C and D). The latter consists of the usual three parts: a pair of cotyledons, the radicle and the plumule. The cotyledons are rather large, thin, and translucent with prominent veins. The radicle and plumule are situated at the same end as the caruncle. Since the mature seed of castor still contains endosperm it is called **endospermic.**

Maize. Maize is an example of a monocotyledonous seed. It is really a fruit (Fig. 16.3) and this is also true of barley, wheat and rice. In all of them the ovary wall (pericarp) is fused with the testa. The maize grain may be any shade of yellow, brown or even black. It is usually concave on the side on which the embryo is situated. The various parts are best seen in a longitudinal section cut through the middle of the grain. The embryo lies on one side of a massive starchy endosperm which forms the bulk of the grain. The outermost layer of the endosperm contains protein grains.

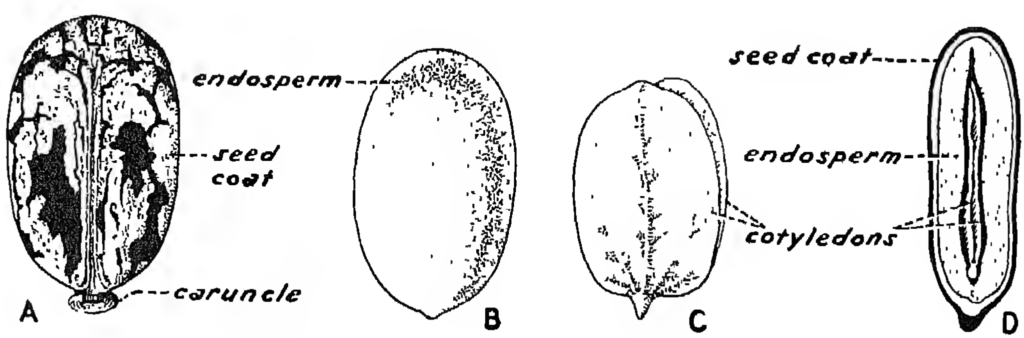

Fig. 16.2. Structure of castor seed. A. View of the flat surface. B. The seed after removal of the seed coats. C. The embryo. D. Longitudinal section of the seed along the narrow axis. Courtesy of the Department of Botany, University of Delhi.

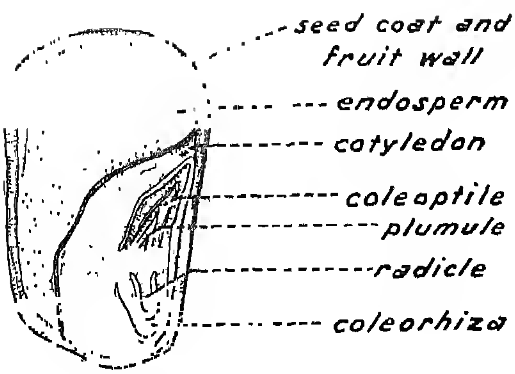

Fig. 16.3. Longitudinal section of a maize 'seed'. Courtesy of the Department of Botany, University of Delhi

The embryo consists of a single large cotyledon; a well-developed plumule covered over by a sheath called **coleoptile**, a short hypocotyl, and a radicle which is also covered over by a sheath called **coleorhiza.** These sheaths are characteristic of the seeds of all cereals and grasses. The single cotyledon is a broad, flat structure lying against the endosperm (Fig. 16.3).

Germination of Seeds

The mature seeds usually do not germinate immediately but remain dormant for some time. During this period if the conditions of storage are adverse, the embryo dies and the seed does not germinate any more, i e , it loses its viability. Under proper conditions the seed germinates to produce a new plant. The resumption of growth of the embryo occurs only under favourable conditions which include a supply of water and oxygen, and a suitable temperature. Light hastens the germination of some seeds but is unfavourable for the others. The first visible indication of germination is the swelling of the seed by the absorption of water, and the softening of the testa. The embryo begins to utilize the reserve food and becomes active. The radicle starts elongating first and emerges from the seed. This is followed by the elongation of the hypocotyl and extension of the plumule beyond the seed. Thus, a seedling is formed. Continued growth of the radicle produces a root which soon develops several branches. Similarly, the plumule continues to elongate and forms the stem and leaves. This is the general pattern of germination but details vary from seed to seed. We shall consider the modes of germination in bean, pea, castor and maize.

Bean. The food is stored in the cotyledons. The emergence of the radicle is followed by the elongation of the hypocotyl carrying upward the two cotyledons and the plumule (Fig 16 4 A to D). As the hypocotyl continues to elongate the cotyledons spread apart. In the meantime the plumule grows rapidly and puts forth the first true, green leaves (Fig. 16 4 E and F). The cotyledons also develop chlorophyll and carry on photosynthesis for some time, but do not assume the form of true leaves. Gradually the food stored in them is consumed and they shrivel and fall off. By this time the plumule has produced the actively growing shoot, and the radicle forms the root with many branches (Fig. 16 4 G).

Pea. The early stages of germination are the same as in bean. However, the hypocotyl does not elongate and, therefore, the cotyledons remain underground. Even though the radicle emerges first, it is the plumule which develops more rapidly forming the stem and leaves. The cotyledons degenerate as the stored food is consumed. By this time the root and shoot are well developed (Fig. 16.5).

Castor. Here the cotyledons are thin and they first serve to conduct food from the endosperm to the embryo. The fatty, massive endosperm is carried up with the cotyledons as the hypocotyl elongates (Fig. 16.6). In a young seedling the cotyledonary leaves remain enclosed in the

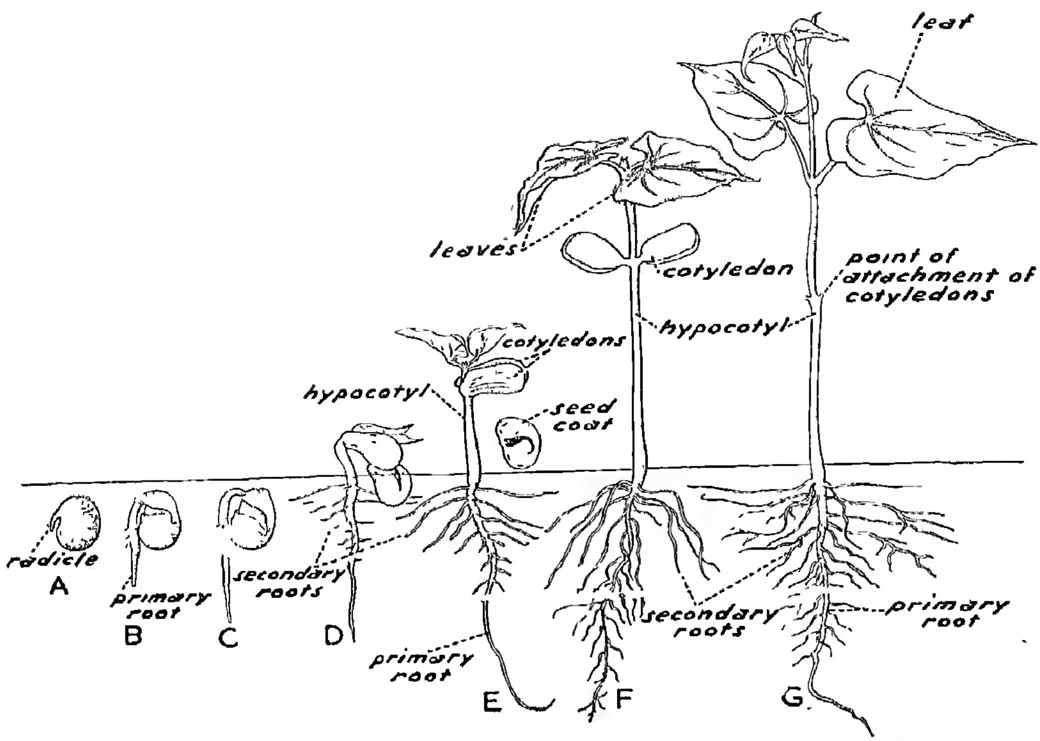

Fig. 16.4. Stages in the germination of bean seed and the establishment of a seedling. Courtesy of the Department of Botany, University of Delhi.

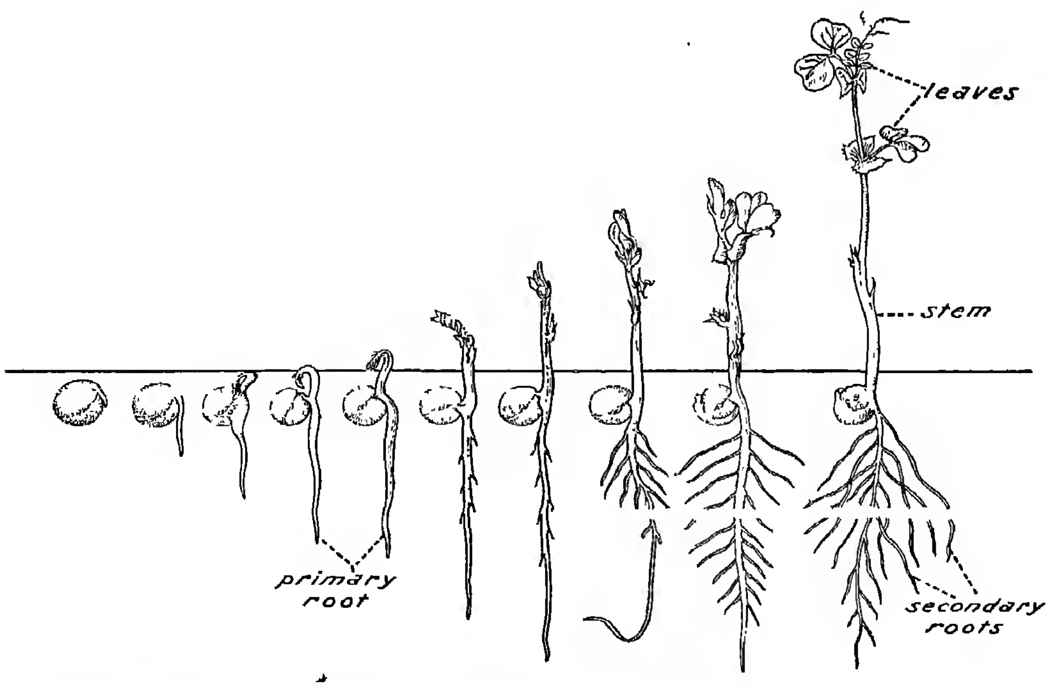

Fig. 16.5. Stages in the germination of pea seed and the establishment of a seedling. Courtesy of the Department of Botany, University of Delhi

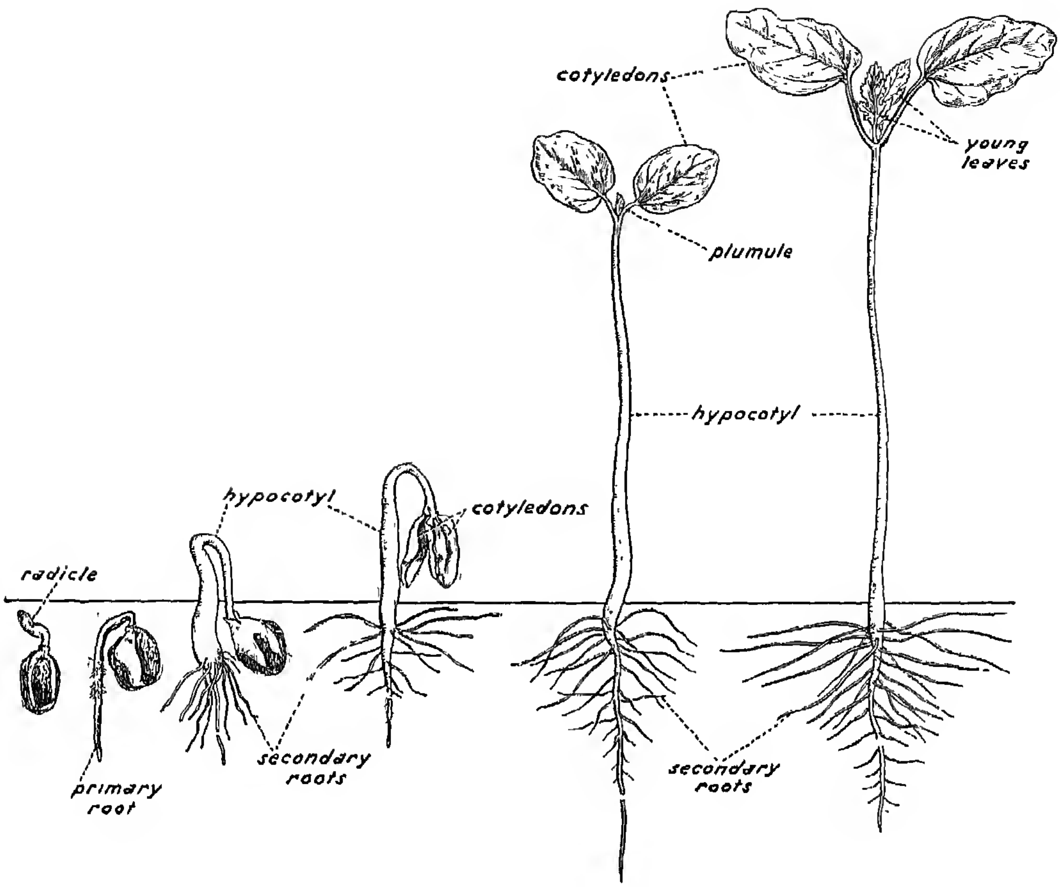

Fig. 16.6. Stages in the germination of castor seed and the establishment of a seedling. Courtesy of the Department of Botany, University of Delhi.

endosperm but after its reserves are consumed, they spread out. The plumule grows very slowly, and until new leaves are formed the cotyledons serve to carry on photosynthesis.

Maize. The single cotyledon absorbs food materials from the endosperm and passes them on to the growing parts The radicle emerges first and is immediately followed by the first leaf. The radicle breaks through the coleorhiza and forms the primary root (Fig. 16.7 A and B). Adventitious roots develop from the junction of the hypocotyl and the radicle forming an extensive fibrous root system The coleoptile keeps pace with the growth of the plumule but ultimately the leaves break through it

Thus we see that the cotyledons either remain underground (**hypogeal**) or they are carried above the soil on the hypocotyl (**epigeal**). The seedling is a young plant which has just emerged from the seed. In due course of time it develops into a sapling and then into an adult plant.

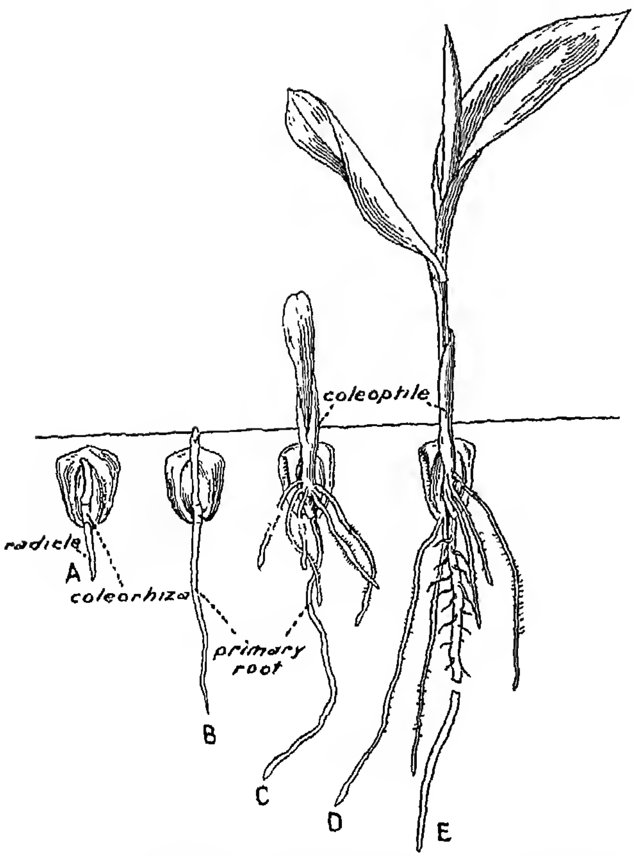

Fig. 16.7. Stages in the germination of maize 'seed' and *the establishment of a seedling.* Courtesy of the Department of Botany, University of Delhi.

Uses

Since the dawn of history the seeds of many plants have been used by man for food In fact the use of cereals has been traced to a period much earlier than recorded history. Wheat and barley were being cultivated at Mohenjodaro (Indus Valley, now in Pakistan) nearly 5,000 years ago. Even today cereals occupy an important place in our diet. Seeds are also important sources of fibres (cotton), oil (mustard, coconut and 'til'), drugs (nux-vomica) and spices (cardamom) Indeed, seeds are used by man more than any other part of the plant

SUMMARY

Seeds are the fertilized and matured ovules. A typical seed consists of one or two seed coats, and a miniature plant or embryo The embryo has three parts: one or two cotyledons, a plumule and a radicle. Most seeds have a reserve of food material either in the cotyledons or in the endosperm. *Seeds containing* endosperm at *maturity* are called endospermic; those without it are non-endospermic

Three important external conditions necessary for the germination of seeds are: moisture, suitable temperature and oxygen. When the seed germinates the radicle forms the root, and the plumule forms the shoot. In some plants the cotyledons are carried above the soil during germination. In others they remain in the soil. Seeds are important sources of food, spices, drugs, oils and many other useful products.

QUESTIONS

1. Distinguish between
   (a) endospermic and non-endospermic seeds.
   (b) hypogeal and epigeal germination of seeds.
2. Compare the structure and germination of the bean seed with that of castor
3. How will you show whether dry gram seeds, as sold in the market, are dead or alive?
4. When ovules start maturing into seeds, an endosperm is almost always present What becomes of this endosperm in the mature non-endospermic seeds?
5. If a seed does not germinate, does it mean that it is dead?
6. Which is better for the plant—reproduction by seeds, or by tubers, rhizomes, etc? Why?

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CHAPTER 17

The Fruit and Its Dispersal

THE act of fertilization stimulates the growth not only of ovules, but also of the ovary which becomes the fruit Only those fruits which are well-nourished reach maturity, the rest stop growing at different stages of development and may fall off. This phenomenon of premature falling of fruits is common in mango and several other plants.

The popular usage of the term fruit differs considerably from its scientific usage. A layman thinks of fruit as something fleshy, sweet or sour that can be eaten without cooking To a botanist, however, the fruit means only a ripened ovary Thus, to him chillies, brinjals and peas are as much fruits as mangoes, melons, apples, oranges and peaches Similarly some plant materials, commonly spoken of as 'seeds' (such as wheat or maize grains, coriander and fennel 'seeds') are in reality fruits.

Sometimes other parts of a flower, such as the sepals and the receptacle, may also undergo changes and form a part of the fruit. The apple, for instance, is made largely of the enlarged receptacle (Fig. 17 1), while the ovary lies in the centre of the fruit and is inedible. In the strawberry the thalamus swells and bears a large number of fruitlets on its surface In *Dillenia* the calyx persists and becomes fleshy forming a prominent part of the fruit. In the cashew the receptacle becomes fleshy forming a fruit-like body the cashew apple, while the actual fruit is attached to its upper portion (Fig. 17.2).

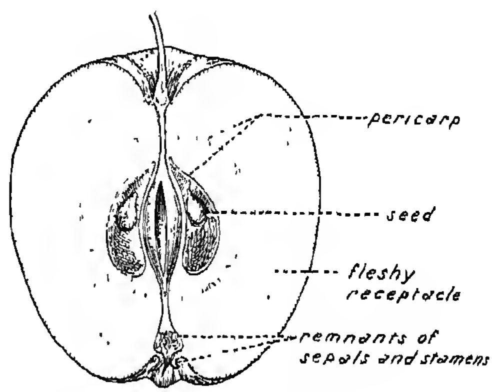

Fig. 17.1. Longitudinal section of an apple fruit. The edible part is derived from the swollen receptacle while ovary proper forms the central cartilaginous part. Courtesy of the Department of Botany, University of Delhi.

The extent of development of the ovary wall into fruit wall or **pericarp** is highly variable. In the wheat grain, for example, the ovary wall grows but little and becomes fused with the seed coat. The two together form

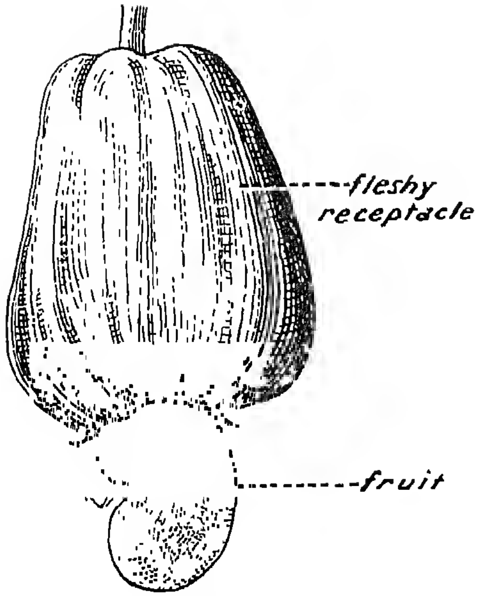

Fig. 17.2. **Fruit of cashewnut. The actual fruit develops from the ovary while the fleshy 'cashew apple' is derived from the swollen receptacle.** Courtesy of the Department of Botany, University of Delhi

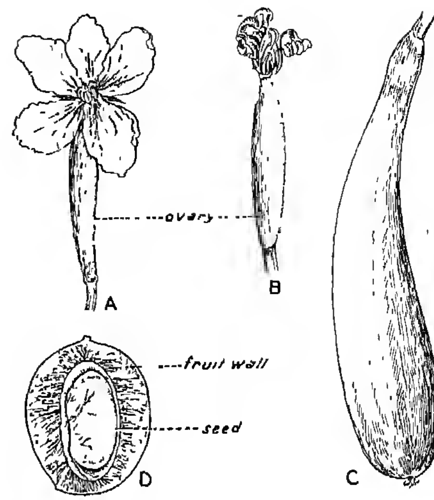

Fig. 17.3. **A. to C. Development of a gourd; there is a marked increase in the dimensions of the ovary from the time of pollination (A) to the stage of maturity (C). D. Longitudinal section of a mango; of the three regions of the fruit wall, only the middle is fleshy.** Courtesy of the Department of Botany, University of Delhi

the bran In mango the ovary wall undergoes more important changes. It becomes differentiated into the green or yellow-red skin, the middle fleshy part and the inner hard woody portion enclosing the seed (Fig. 17 3 D) In the water melon and some giant gourds, the ovary is only a few centimetres long but the fruit becomes gigantic (Fig. 17 3 A to C). The time required for different fruits to attain maturity varies from a few weeks to several months. However, the large fruit of the double coconut palm (*Lodoicea sechellarum*, Fig. 17.4) is exceptional in that it takes about ten years to ripen.

Some mature fruits open (dehisce) along one or more regular lines or pores. Such fruits are known as **dehiscent** (Fig 17 5). There are others, such as those of sunflower, wheat, brinjal and tomato, which do not open or dehisce These fruits are known as

Fig. 17.4. **Fruit of double coconut; it takes about ten years to ripen.** Courtesy of the Department of Botany, University of Delhi.

indehiscent and a few examples of these are shown in figure 17.6. Some special types of fruits are shown in figure 17.7.

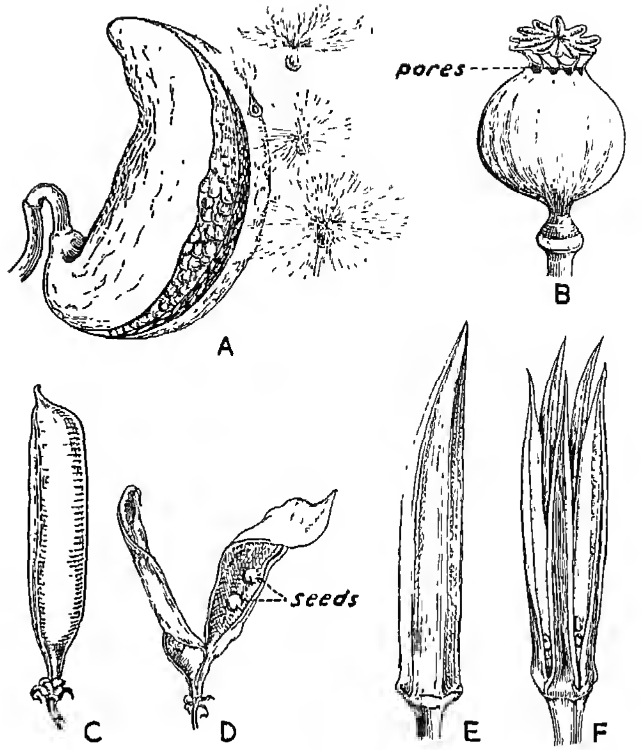

Fig. 17.5. Examples of dehiscent fruits. A. Milkweed; the fruit dehisces along one side only. B. Poppy; the seeds are liberated from the pores below the 'crown'. C and D. Pea; the mature fruit opens along both the sides. E and F. Lady's finger, the fruit opens along several lines. Courtesy of the Department of Botany, University of Delhi

In recent years biologists have been able to grow mature fruits in the laboratory similar to those formed in Nature. The ovaries from pollinated flowers are removed and sown (cultured) on an artificial nutrient medium (containing sugar, some salts and a few other compounds) in test tubes (Fig 17 8). In two to six weeks the ovaries undergo normal development and mature into fruits with healthy seeds. In this way, the fruits of tomato, candytuft, and several other plants have been produced from isolated ovaries. Such experiments are useful in understanding what substances are taken up by the developing fruits from the plant.

DISPERSAL OF SEEDS AND FRUITS

If you have ever tramped through a patch of weeds in early summer, you may have found your trousers and socks covered with small, spiny or sticky seeds and fruits (Fig 17.9). You perhaps waited till you got home or reached some other suitable shelter before you tried to pick the sticking seeds off your clothes Possibly you had to take your shoes off to remove the needle-like 'seeds' of several grasses which were pricking your feet In your fury you perhaps tossed them far away You may be surprised to learn that in so doing you did these weeds a great service Through your agency their seeds may have reached a favourable spot for germination When these seeds germinate, fresh areas of land will be covered by the plants. Again, some of you might have also noticed sheep grazing in the fields and carrying a variety of spiny seeds and fruits tangled in their fur Being fixed to the ground, the plant itself has no chance of moving Yet most plants manage to

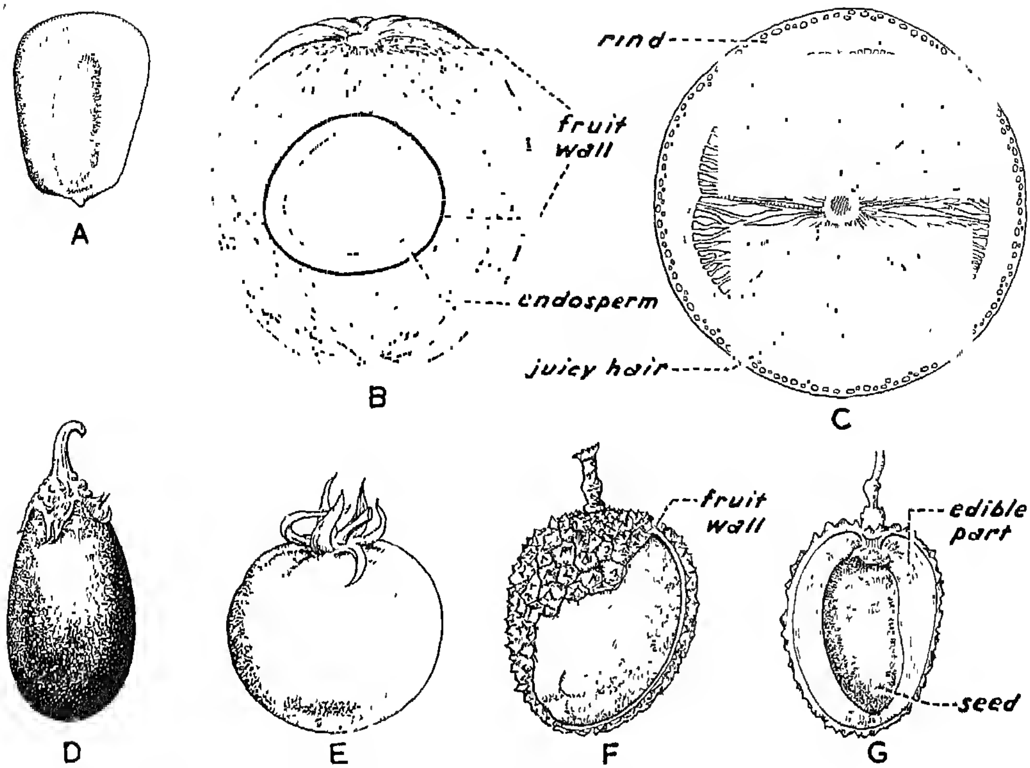

Fig. 17.6. A. Maize; the seed coat and the fruit wall are completely fused to form the 'bran'. B. Coconut; the section shows the fruit wall whose innermost part becomes stony. The edible 'meat' and the 'milk' are both endosperm tissue. C. Orange The transverse section shows the edible juicy hairs which develop from the innermost part of the fruit wall. D. Brinjal. E. Tomato. F and G. Litchi, the edible part in this fruit is an outgrowth of the seed. Courtesy of the Department of Botany, University of Delhi.

extend the range of their occurrence due to the great travelling abilities of their seeds.

The dispersal of seeds has another biological significance. Many plants produce enormous quantities of seeds. If all the seeds of a tree fall and germinate below it, there will be an acute competition for their basic requirements, namely light, minerals and water. Chances are that most or all of the seedlings would die out due to overcrowding. There are many interesting ways for the transport of seeds away from the immediate vicinity of the parent plant In addition to making an accidental use of natural agencies like wind, water and passing animals, plants often have their own mechanisms which help to shoot their seeds away.

Dispersal by Wind and Animals

Study figures 17.10 and 17 11 showing some common seeds and fruits adapted to be carried away by wind A majority of such wind-carried seeds are destroyed in various ways or are transferred to places where their successful germination is impossible. Only

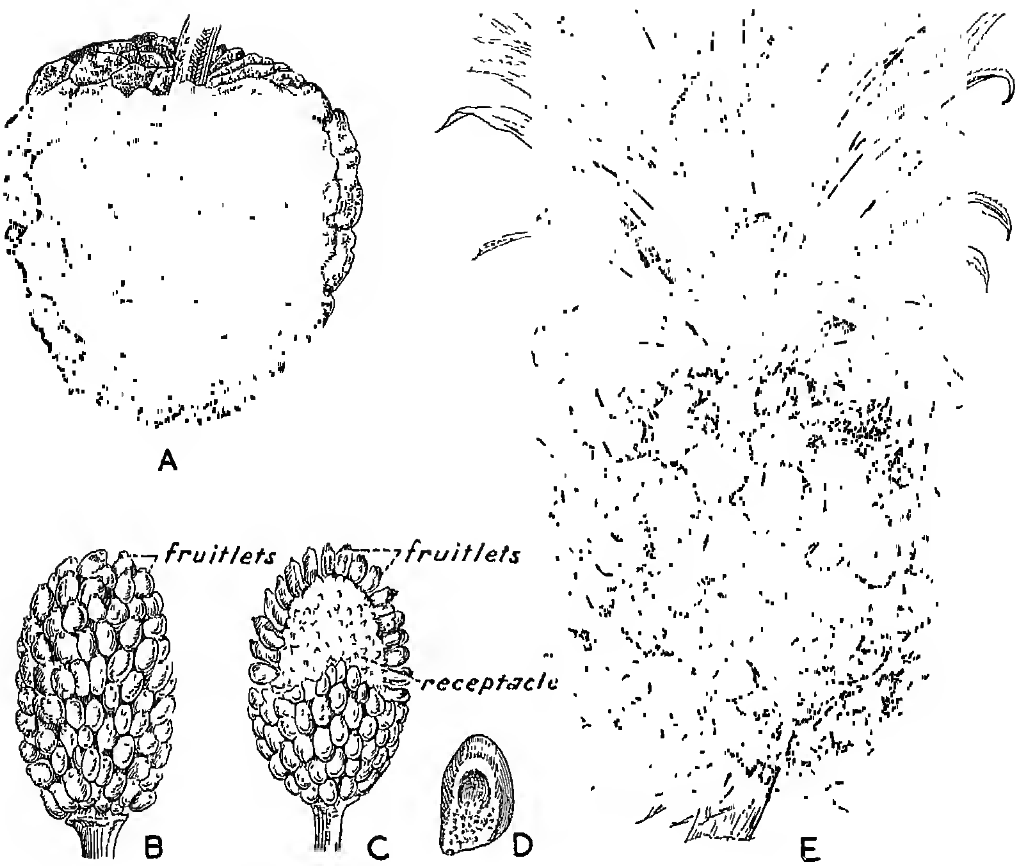

Fig. 17.7. Some examples of special types of fruits. A. Custard apple; this fruit develops from a large number of free ovaries borne in a single flower. All the ovaries ripen simultaneously and form a common unit. B to D. Buttercup; here the ovaries of a flower ripen into separate indehiscent fruitlets all borne on the same receptacle. In C, some of these have been removed to expose the receptacle. A single ripe fruitlet is enlarged in D. E. Pineapple; this fruit is derived from the ovaries of a large number of flowers of an inflorescence. Courtesy of the Department of Botany, University of Delhi.

a small proportion of them are deposited in the right place. However, such plants are prolific seed producers so that at least some of the seeds would find favourable locations for growth.

Several types of appendages on seeds and fruits (Fig 17 12) help them in their dispersal through the agency of animals. The mud in any pond contains many seeds and wading birds such as herons carry the mud-coated seeds with them when they fly. The famous biologist, Charles Darwin, once collected the mud from the foot of a bird and placed it in a pot which he watered from time to time And can you imagine what he got? He obtained 80 small plants growing out of that mud! Some wading birds may migrate to far off places and thus carry the seeds to newer areas.

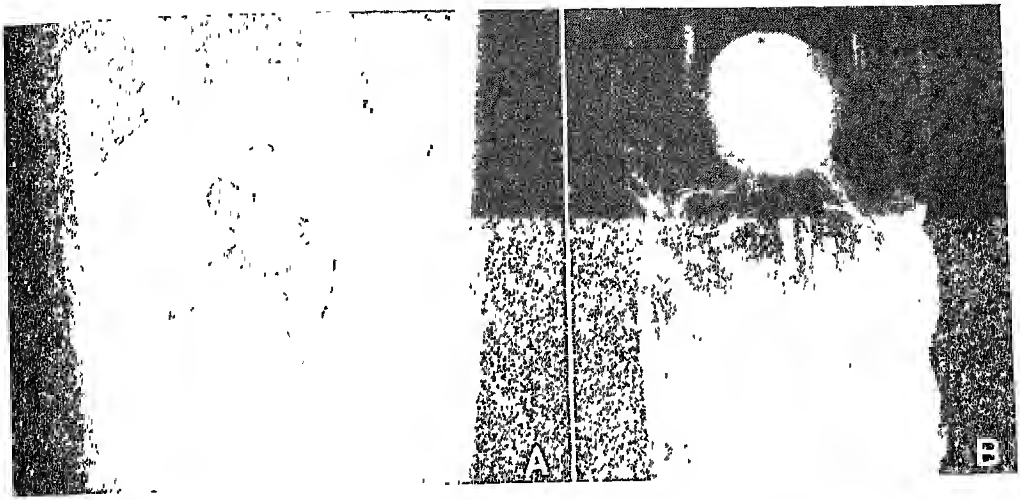

Fig. 17.8. Test tube fruits of tomato. The ovary from a pollinated flower, cultured on a nutrient medium (A), matures into a tomato fruit after six weeks (B). Courtesy of P S. Sabharwal, Department of Botany, University of Delhi.

Fig. 17.9. Spiny fruits and seeds sticking to the clothes of a young biologist tramping through a patch of weeds. Courtesy of the Department of Botany, University o Delhi

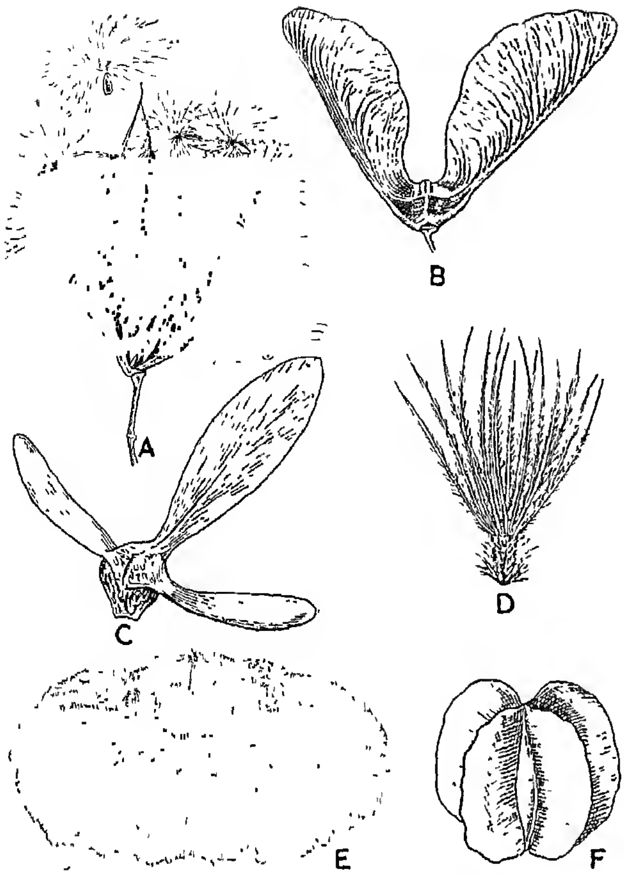

Fig. 17.10. Seeds and fruits dispersed by wind. A. Dehiscing fruit of a milkweed (*Asclepias*), note the seeds with tufts of silky hair being blown about by wind. B, C and F. Winged fruits of maple (*Acer*), *Hiptage*, and *Combretum*. D. Shaving brush type of fruit of *Tridax*, a common weed. E. Seed of *Oroxylon* with a membranous wing. Courtesy of the Department of Botany, University of Delhi.

Fig. 17.11. A dehiscing fruit of milkweed (*Asclepias*). Note the seeds with silky hairs. Courtesy of Hardev Singh, Department of Botany, University of Delhi.

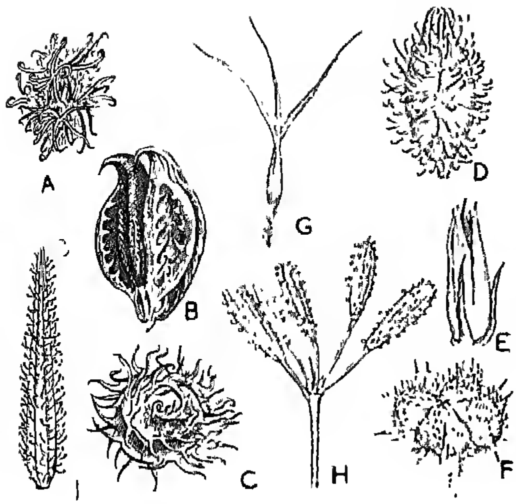

Fig. 17.12. **Fruits dispersed by animals. The spines and hooks cause the fruits (A to G) to be caught in the fur of animals, clothing of mankind, or on passing vehicles. Some fruits (H and I) have sticky hairs which readily adhere to animals. A.** *Pupalia.* **B.** *Martynia.* **C.** *Medicago.* **D.** *Xanthium.* **E.** *Achyranthes.* **F.** *Tribulus.* **G.** *Aristida.* **H.** *Boerhaavia.* **I.** *Plumbago.* Courtesy of the Department of Botany, University of Delhi.

Fleshy fruits have the special advantage in that they are eagerly sought after by animals including man. You have only to recall to your mind the wide variety of fruits whose seeds you toss away after munching their fleshy parts. In this process, at least some seeds become favourably planted. Man may also carry some seeds unintentionally in his automobiles, trucks, aeroplanes and clothing. A botanist once stood at the gate of a church and brushed out the dust from the trouser-cuffs of several devotees. On sowing this he got as many as 50 plants!

Long-range Dispersal by Man

Man plays a very important role in the long range dispersal of plants. In his migrations from place to place, he not only carries his personal belongings but also animals and plants. Moreover, if a particular species of plants appeals to his fancy or suits his needs, he tries to acquire its seeds thus bringing about an effective spread of the plant concerned. A number of plants now familiar to most of you were unknown in our country four centuries ago. Many of them are known to have come with the foreign invaders and visitors. A Muslim pilgrim Baba Budan is said to have imported eleven seeds of coffee on his return journey from Mecca about 250 years ago. He planted these seeds on the Kudre Mukha hill in Mysore. Systematic cultivation of this plant later resulted in the famous coffee plantations in South India. The Portuguese were responsible for bringing (or introducing, as it is called) into our country many plants, notably cashewnut, tapioca and pineapple.

The date palm was brought into India by Alexander and his soldiers from Iran and Arabia. The litchi came from China towards the end of the 17th century.

These are examples of wilful spread of plants by man. Several plants have also been spread unconsciously. One of the most interesting examples of unintentional introduction is that of the water-hyacinth (*Eichhornia crassipes*). It was brought to Bengal by an Englishman named Morgan who was fascinated by its flowers (Fig. 17.13). By sheer accident it reached the river near Narayanganj (now in East Pakistan) where it multiplied so rapidly that boating became impossible. This was aptly named 'Terror of Bengal'. Some other weeds like the prickly poppy (*Argemone mexicana*) have

had a similar history. Plants used as packing material may be taken to far off countries and become wild there

Thus although the plants are themselves non-motile, they send their seeds on far off journeys and some of them rank among the world's greatest globe-trotters

Fig. 17.13. Water-hyacinth nicknamed as 'Terror of Bengal'. Courtesy of the Department of Botany, University of Delhi

SUMMARY

Following fertilization the ovules mature into seeds and the ovary becomes transformed into a fruit. Sometimes the sepals and the receptacle may also form a part of the fruit The wall of the fruit is known as pericarp. In some types of fruits it becomes differentiated into three regions.

Depending upon whether they open out to scatter their seeds or remain closed throughout, fruits are classified into dehiscent and indehiscent types

Various modifications of fruits and seeds are helpful in their short-distance dispersal by wind, water, and animals

Man is the most important agent for long-distance dispersal of plants Fruits provide us food, drugs, fibres, spices and many other useful products.

QUESTIONS

1. Mango trees produce a bumper crop one year and a very light crop the next year. What could be the reason for this?
2. How does the popular usage of the term 'fruit' differ from its botanical usage?
3. Name five fruits of the summer season and five of the winter season. Indicate the nature of the edible part in each case.
4. Do all fruits contain seeds? If not, what happens to the ovules contained in the ovary?
5. Name three seedless fruits. Ask your teacher how such fruits are produced.
6. Mango trees produce a very large number of flowers but only a small percentage of them yield fruits. Explain.
7. A newly laid lawn often becomes infested with weeds. Spot out the two most important weeds and explain how they continue to persist in the lawn and spread from one place to another.
8. From the point of view of human beings which fruits would be useless without seeds? Which fruits will be more desirable if they are seedless?

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CHAPTER 18

Gymnosperms

IN summer months some of you might have gone to hill stations like Simla, Mussoorie, Nainital and Kodaikanal Almost the first thing that catches one's attention from a distance are the graceful, tall and conical trees with narrow needle-shaped leaves and a turpentine-like smell (Fig. 18.1). These are the pines, cedars, firs and cypresses Their wood is extensively used for constructional purposes and for making packing cases Another member, *Cycas circinalis*, occurs wild in parts of Andhra Pradesh, Kerala and Madras This plant resembles a palm in having a columnar stem and a crown of large leaves. One species, *C. revoluta*, is grown all over India in parks and gardens You might also have seen the thujas—dark green, neatly trimmed conical plants—lining the avenues in parks and gardens. All these—pines, cedars, firs, cypresses and thujas—belong to a distinct group of plants botanically known as gymnosperms. The name implies that the seeds are not enclosed in an ovary but are borne exposed on leaf-like structures called **sporophylls.** These plants are generally evergreen, xerophytic trees or shrubs.

The gymnosperms resemble the angiosperms in several respects. In both, the plant body is differentiated into the root, stem and leaves; there is a secondary increase in the thickness of root and stem, and there is production of pollen grains, pollen tubes and seeds. The most important difference between the two is that in the angiosperms the ovules—which finally mature into the seeds—are enclosed in the ovary (Fig 18 2 A); while in the gymnosperms the ovules are borne on the surface of flat leaf-like structures (Fig. 18.2 B) and the pollen grains germinate directly on the ovule. The sporophylls are generally borne in large, woody cones which you must have seen hanging from the branches of a pine tree

In the internal structure of the ovule also, the gymnosperms differ markedly from the angiosperms. In the angiosperms the female gametophyte (embryo sac) is very small and contains only eight nuclei (Fig 18.2 C) The gametophyte of gymnosperms, on the other hand, is very large and contains thousands of cells (Fig. 18.2 D). It also bears a few archegonia as in fern (*see* Chapter 23). In the angiosperms one male gamete fertilizes the egg and the other fertilizes the secondary nucleus (double fertilization). In the gymnosperms only the egg is fertilized (single fertilization). The two groups of plants can be further distinguished by looking at a cross section of their woods The wood of angiosperms shows large circular pores called the xylem

Fig. 18.1. Cedars (*Cedrus deodara*) **photographed at Chakrata. Note the graceful conical appearance.** Courtesy of Hardev Singh, Department of Botany, University of Delhi.

vessels (Fig. 18.2 E), while that of gymnosperms lacks xylem vessels and has only tracheids (Fig. 18.2 F).

Although all gymnosperms have several features of structure and reproduction in common, there also exists a wide degree of variation in the individual organs. The following account refers only to one genus, namely, *Pinus*.

PINUS

The pines are large trees having a conical form (at least when young) because the lower branches are longer than the upper (Fig. 18.3) The plant bears two types of branches—the long shoots which have an unlimited growth, and the short or dwarf shoots with a very limited growth (Fig. 18 4). The dwarf shoots of some species bear only three needles while those of other species have two or five

Reproduction

The reproductive organs comprise the male cones (Fig. 18 5 A) and the female cones (Fig. 18.4). A male cone consists of numerous little **microsporophylls,** arranged spirally on the cone axis (Fig 18.5 C) Each microsporophyll bears two **microsporangia** (pollen sacs) on its lower surface (Fig. 18 5 B) As the pollen sacs dehisce, clouds of yellow pollen are carried away by wind and form the so-called sulphur showers. All the trees in the forest shed their pollen about the same time, generally in spring The pollen is very light and each

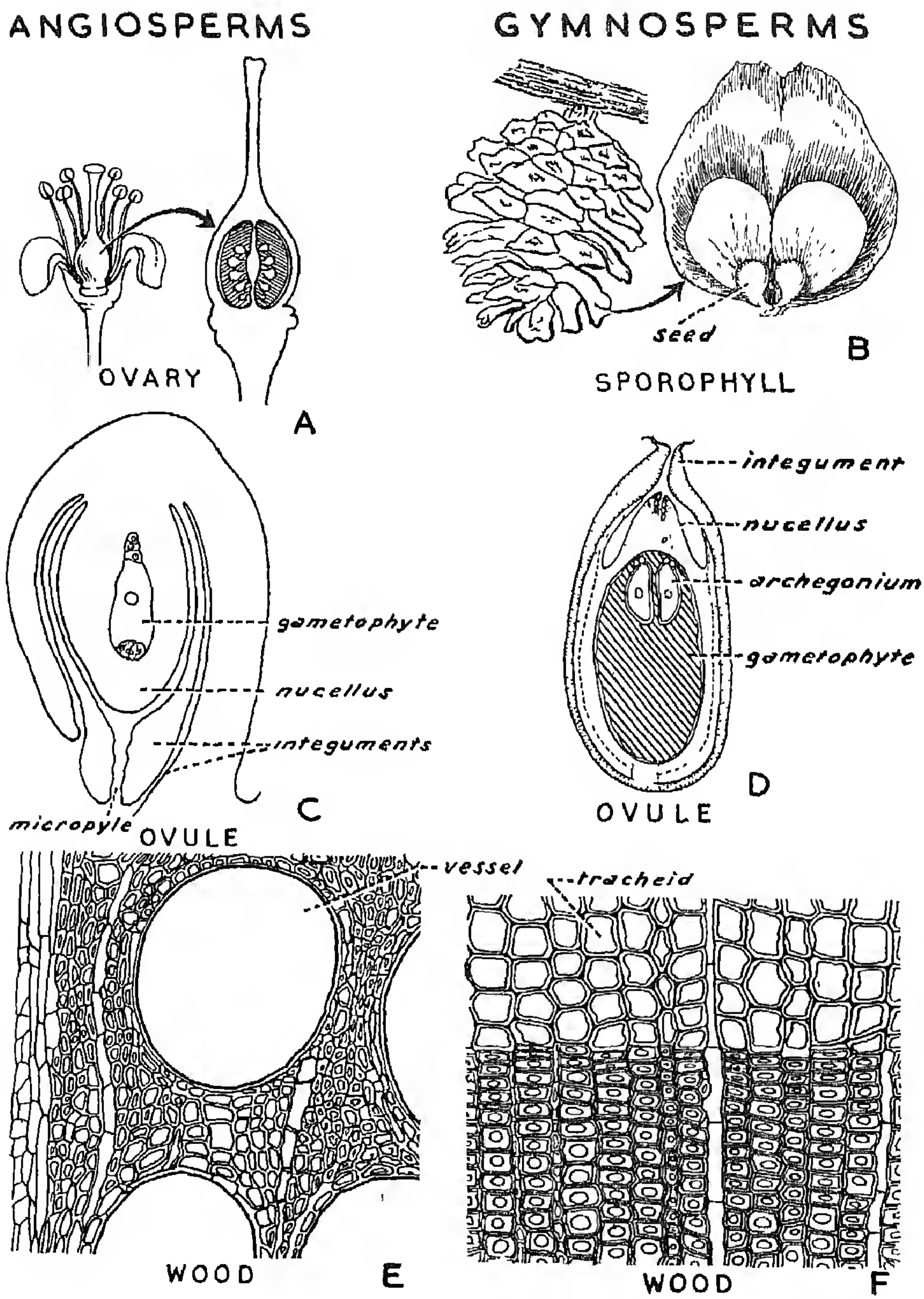

Fig. 18.2. Important differences between angiosperms and gymnosperms. Courtesy of the Department of Botany, University of Delhi.

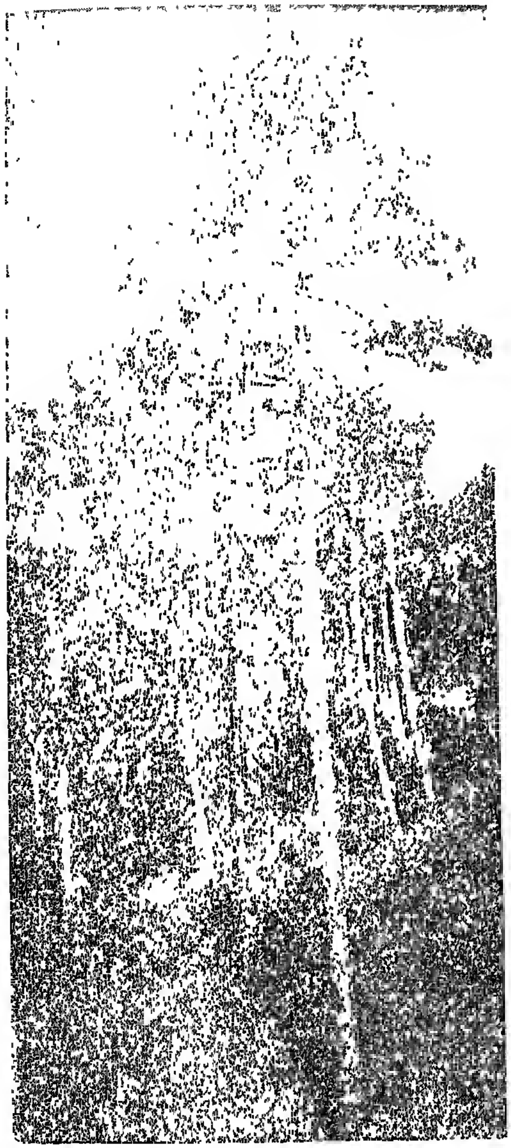

Fig. 18.3. A stand of pine trees (*Pinus roxburghii*). Courtesy of Hardev Singh, Department of Botany, University of Delhi

grain bears two wing-like structures (Fig 18 5 D) which can be easily seen under the microscope After discharging the pollen grains, the male cones shrivel up

The female cones occur in groups of two or three and remain on the tree for nearly three years They first appear as small reddish structures near the tips of the branches Each cone consists of a very large number of scale-like appendages called the **bract scales** borne spirally on a central axis. In the axil of every bract scale there is another flattened structure called the **ovuliferous scale** which bears two ovules on its upper surface close to the axis (Figs 18.2 B and 18 7A)

The young ovules secrete drops of a sweet fluid called the pollination drop The air at this time is full of pollen and some of the pollen grains drift down between the scales The pollen grains caught in the pollination drop are drawn in through the micropyle

The female cone grows further only after he ovules have been pollinated The stalk of the cone bends so that it now hangs downward The bract scales remain small while the ovuliferous scales grow considerably and become woody. The neighbouring scales come in close contact, and the female cone becomes compact and closed (Fig. 18.6 A)

The ovule consists of three parts The outermost is the integument which encloses the nucellus and this in turn contains the female gametophyte (Fig 18.7 B) The integument has a narrow opening, the micropyle (Fig. 18.7 A and B) Through this, the pollen grains land on the nucellus after floating in the pollination drop Here they germinate and give out pollen tubes which travel through the nucellus down to the female gametophyte The latter bears three to five archegonia at its top. Each archegonium has a large egg cell and a few neck cells The pollen tube carries two male gametes and liberates them into the egg cell. One of the male gametes fuses with the egg while the other degenerates.

The ovule undergoes marked changes after fertilization The integument hardens to

form the seed coat (Fig. 18.7 C) which together with a part of the ovule-bearing scale develops a large wing. The zygote develops into the embryo. The embryos of pines are similar to those of the dicotyledonous angiosperms except that they have several cotyledons each instead of just two.

As the seeds mature the cone dries up and turns brown. The scales shrink and separate from each other. The cone opens once again (Fig. 18.6 B) and sheds the winged seeds which are dispersed by wind.

Economic Importance

The cycads are important as a source of sago starch which is obtained both from their stems and seeds. Several centres of sago industry flourish in Kerala. From the commercial point of view, pines and cedars are the most important of all gymnosperms. They are the richest yielders of timber, turpentine, paper, essential oils and tannin. While the wood of pines finds its chief use in the making of only cheap articles such as doors, vats, and packing cases, that of deodar (*Cedrus deodara*) is used for furniture. This wood is strong and insect-resistant. The resin obtained from pines is used in

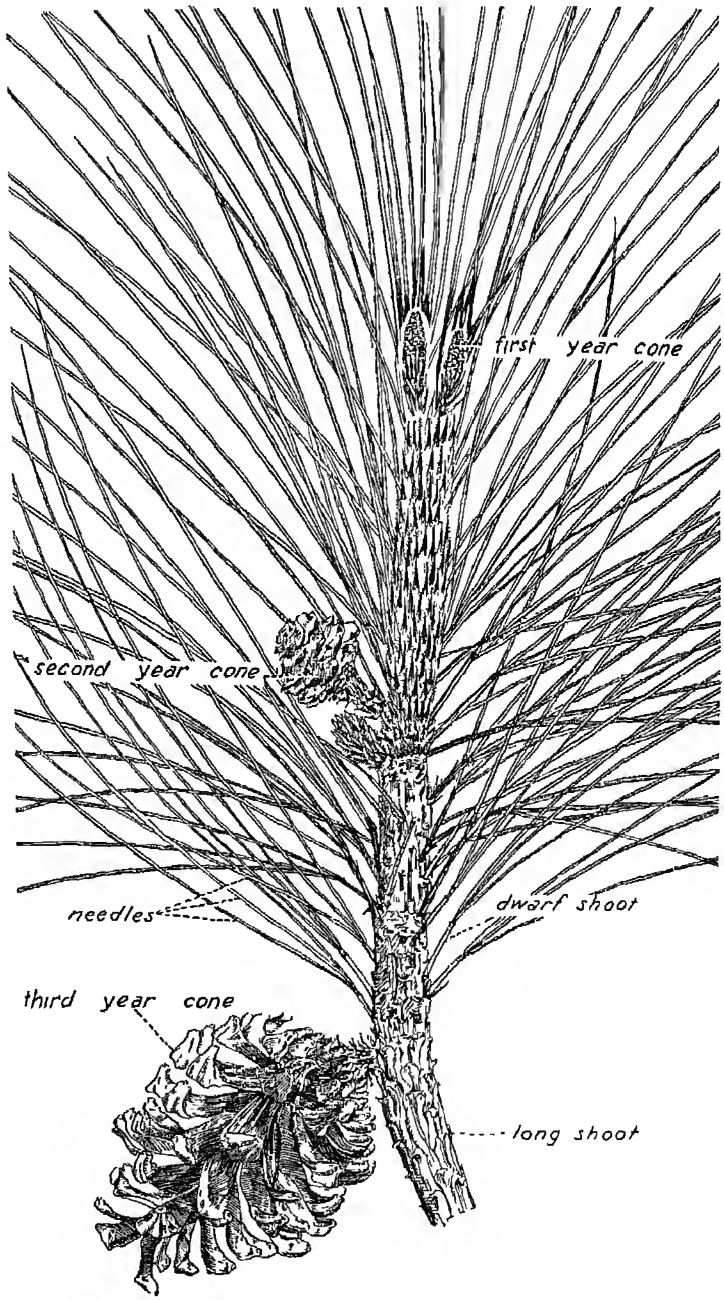

Fig. 18.4. A twig of pine showing dwarf and long shoots, needle-like leaves and female cones. Courtesy of R N Konar, Department of Botany, University of Delhi.

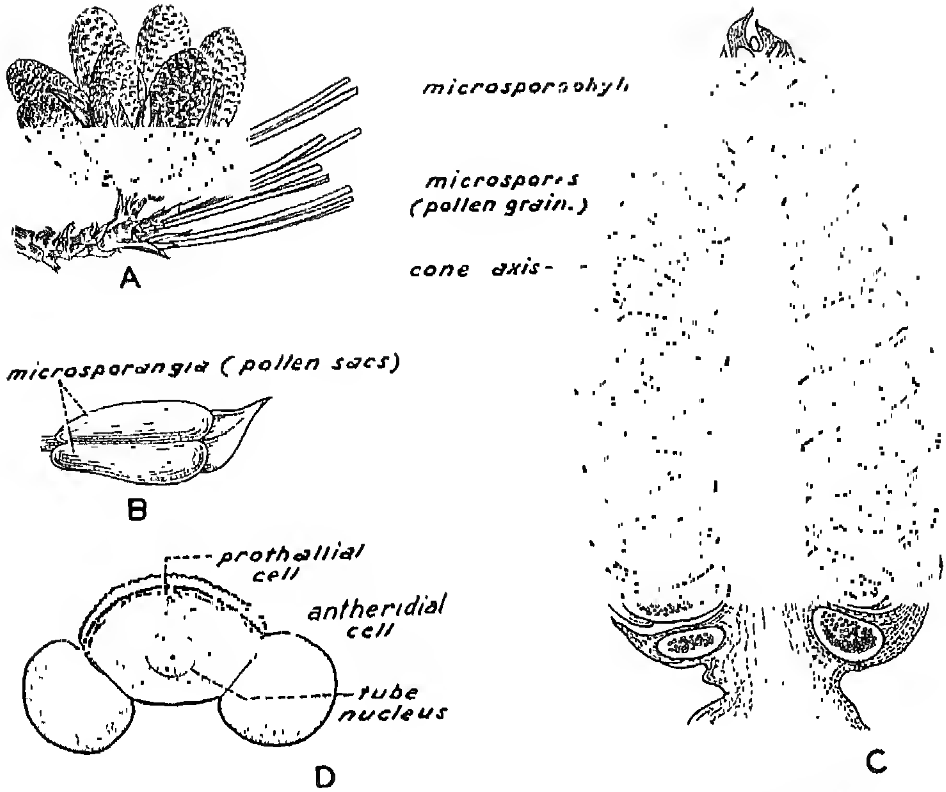

Fig. 18.5. Male cones of *Pinus*. A. Cluster of male cones. B. Microsporophyll. C. Longitudinal section of a male cone. D. Winged pollen grain. Courtesy of R.N. Konar, Department of Botany, University of Delhi.

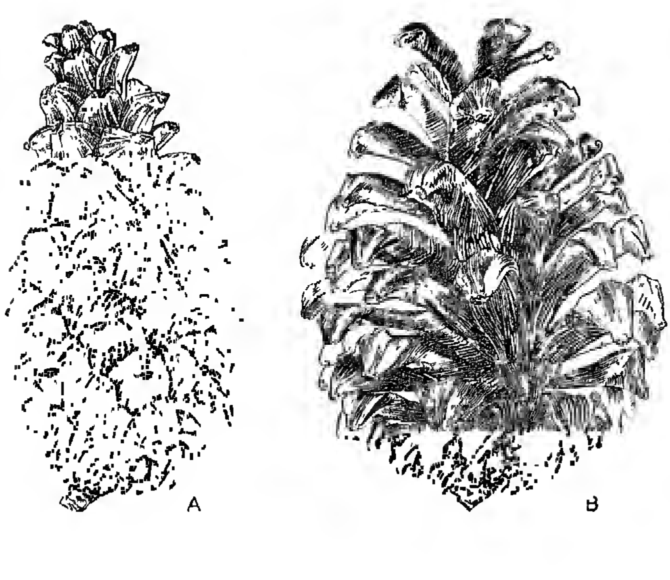

Fig. 18.6. Female cones of *Pinus roxburghii*, the one on the right has shed its seeds. Courtesy of R N. Konar, Department of Botany, University of Delhi.

varnishes, ointments, plasters, sealing wax, shoe polish and many other products Other well-known resins obtained from conifers are 'kauri copal' sandarac and amber The paper for your daily newspapers comes from the wood of gymnosperms The 'chilgozas' which you fondly consume during winter are the seeds of *Pinus gerardiana*, growing in the inner valleys of the Himachal Pradesh *Ephedra* has recently gained importance as the source of a drug called ephedrine which is widely used against asthma and other respiratory troubles *Biota* and *Thuja* are common garden favourites in many parts of Northern India. They have an elegant, long and tapering form.

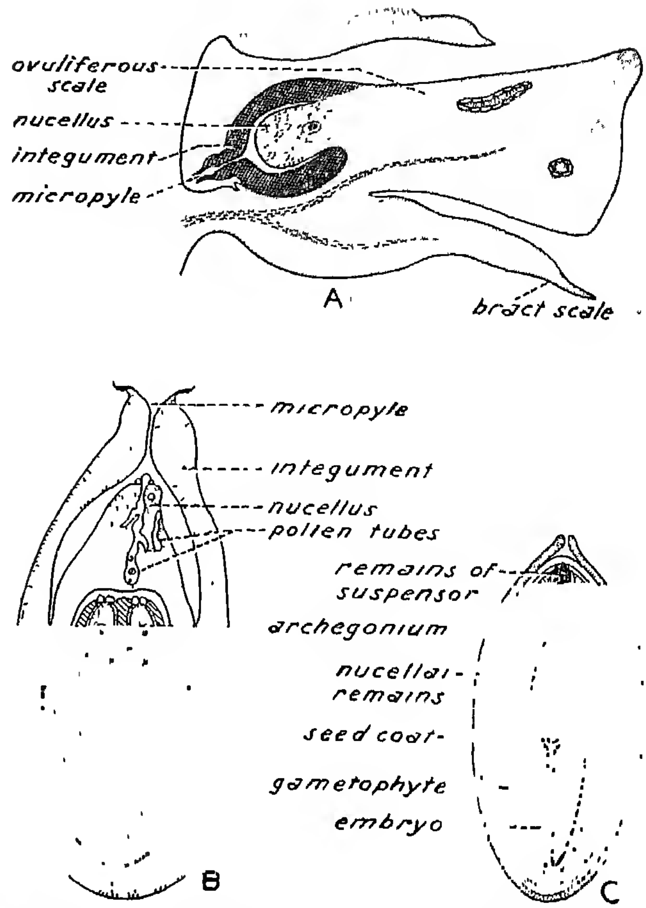

Fig. 18.7. The ovule and embryo of *Pinus* A. Longitudinal section of the bract and ovuliferous scales. B. Longitudinal section of ovule at the time of fertilization. C. Longitudinal section of a mature seed. Courtesy of R N. Konar, Department of Botany, University of Delhi.

SUMMARY

The gymnosperms are graceful, evergreen, xerophytic trees or shrubs whose seeds are not enclosed in an ovary. They differ from the angiosperms in several important characters such as the position of ovules, organization of the female gametophyte, the structure of the wood, and so on,

Pinus is a beautiful tree with needle-like leaves. It bears two types of branches—long shoots and dwarf shoots The male cones are produced in clusters while the female cones occur in groups of two or three at the apices of the branches on the same tree. A male cone has an axis around which the

microsporophylls are attached spirally. Each sporophyll bears two microsporangia. A large number of winged pollen grains are produced in each pollen sac

The female cone also comprises a number of scales borne around a central axis. Each scale bears two ovules on its upper surface. The main body or nucellus of the ovule is enveloped by an integument and contains a female gametophyte. There may be two or three archegonia in each gametophyte The pollen grains are carried to the ovulate cones by wind Some of them are caught in the pollination drop and reach the nucellus. Here they germinate to produce pollen tubes which carry the sperms to the archegonia. When the tip of the pollen tube bursts, it discharges its contents in the archegonium and one of the sperms fertilizes the egg The zygote develops into an embryo The ovule becomes a seed.

Besides their ornamental value, the gymnosperms are also important in many other ways Sago, timber, paper, and essential oils are examples of the useful products obtained from gymnosperms

QUESTIONS

1. What do you understand by the following terms: (a) evergreen trees, (b) 'sulphur showers'; (c) dwarf shoots, (d) pollination drop; (e) naked seeds; (f) pine needles ?
2. With the help of diagrams alone, bring out the essential differences between angiosperms and gymnosperms.
3. Name some gymnosperms other than those mentioned in this chapter

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CHAPTER 19

Microbes and Viruses

AMONG the large diversity of living organisms around us a great many are invisible to the naked eye because of their small size Consequently their importance often remains unappreciated by the layman. All these microscopic unicellular organisms are referred to as microbes (Gk. *mikros*=small, *bios*=life) Although some forms must have been present ever since life began on earth, they remained unnoticed until Leeuwenhoek discovered them in 1676. They come under four chief groups: bacteria, rickettsiae, yeasts and protozoa. The protozoa, about which you will read in detail in Section 3, are distinctly animals, the yeasts—organisms used in making wine and bread—are related to moulds; the bacteria are the simplest and smallest of plants, and the rickettsiae may perhaps be called bacteria of a still smaller size. The viruses—infectious particles that cause the common cold, polio and other diseases—are peculiar 'organisms' sharing the properties of both living and non-living material In this chapter we shall study only bacteria and viruses.

BACTERIA

Bacteria are minute, single-celled plants that are too small to be seen with the unaided eye Like the fungi most of them lack chlorophyll and have to depend on external sources for their food supplies They may be saprophytes, deriving food from dead organic matter, or parasites, obtaining it from the tissues of other living organisms A few forms have pigments similar to chlorophyll and are autotrophic in their mode of nutrition

Occurrence

Bacteria are present everywhere—in air, soil, water, foodstuffs, sewage waste, and on as well as inside animal bodies. They are specially abundant on dead animals and plants and cause their decay. It is almost impossible to think of any place without them They are present at great depths in the oceans, in natural streams, in the snow of polar regions, in hot springs, and even in sulphur springs. Our alimentary canals harbour millions of bacteria and all the ruminating (cud-chewing) animals must have them too in order to digest the cellulose part of their vegetable food.

Morphology

Bacterial cells vary from 0.5 to 3 microns in diameter or length. They are of three

common types : coccus or spherical, bacillus or rod-like, and spirillum or spiral. Sometimes the cells may remain joined together end to end in the form of a filament or they may form small lumps.

The cells possess distinct cell walls composed of proteins and carbohydrates. Unlike higher plants, the walls of most bacteria lack cellulose. Quite commonly, the cell is enclosed in a slime layer or capsule. Capsulated forms of disease producing bacteria are very resistant and are not easily killed or digested in the body. Inside the cell wall is the plasma membrane. The cytoplasm is fairly uniform except for the presence of granules of stored food (Fig. 19.1). In the photosynthetic bacteria the cytoplasm has numerous chromatophores containing photosynthetic pigments.

Most spiral and some rod-shaped bacteria have one or more small hair-like structures called cilia. The number, size and position of cilia vary from species to species. Bacterial cells do not possess organized nuclei of the type found in higher plants. There is no nucleolus, nor any nuclear membrane. However, they do have the essential nuclear material or chromatin in the form of spherical lumps, occurring singly or in pairs. These can be seen only at a very high magnification. Chemically these lumps are made up of twisted strands of deoxyribonucleic acid (DNA). You will read more about this substance in Chapter 52.

Reproduction

The bacteria usually reproduce asexually by simple fission or cell division (Fig. 19.2).

Fig. 19.1. Generalized diagram of a bacterial cell.

Frequently, the newly formed daughter cells may remain joined together forming colonies of various sizes, forms and colours. Under favourable environmental conditions, fission may occur once in every twenty minutes. Thus, starting from one cell, there will be a billion individuals after fifteen hours and two hundred truck loads of bacteria after thirty-six hours. After forty-eight hours their weight would be roughly four times that of the earth. However, such fantastic growth never actually occurs since the multiplication stops due to an exhaustion of food supplies and by the accumulation of excretions, poisonous to their own growth.

Under unfavourable environmental conditions, some bacteria form **endospores** by a condensation of the cytoplasm into a spherical body. This develops its own thick wall and may be liberated by the decay of the parent cell wall. When favourable conditions return, the thick wall cracks and a single new bacterium is formed (Fig. 19.2). One of the most dangerous of the spore forming bacteria is *Clostridium botulinum*. It is found in soil and on vegetables. Its spores can stand immersion in boiling water. Food contaminated by this bacterium becomes highly poisonous.

Nutrition and Growth

Bacteria can utilize almost any type of organic matter for their growth. Some species grow only in the presence of oxygen (aerobes); others can grow with or without oxygen (facultative aerobes), and still others can exist only in the absence of oxygen (anaerobes). The various aspects of bacterial physiology are studied by culturing them on a broth or soup rich in vitamins and proteins. The medium can be either liquid or it can be made semi-solid by adding agar-agar. When all the constituents have been mixed in the right proportion, the medium

is poured into test tubes. The test tubes are plugged with non-absorbent cotton wrapped in a piece of muslin Prior to inoculation with the desired organism, it is essential that all the bacteria already present on the surface of the glassware and instruments are killed This is achieved by sterilizing the tubes in a pressure cooker or an autoclave at a temperature of 110-120°C and 15 lb pressure for about 15 minutes. After the tubes have been sterilized, they are cooled and inoculated with the required bacterium under completely sterile conditions. The various steps in the preparation of the medium and setting up of a bacterial culture are shown in figure 19.3.

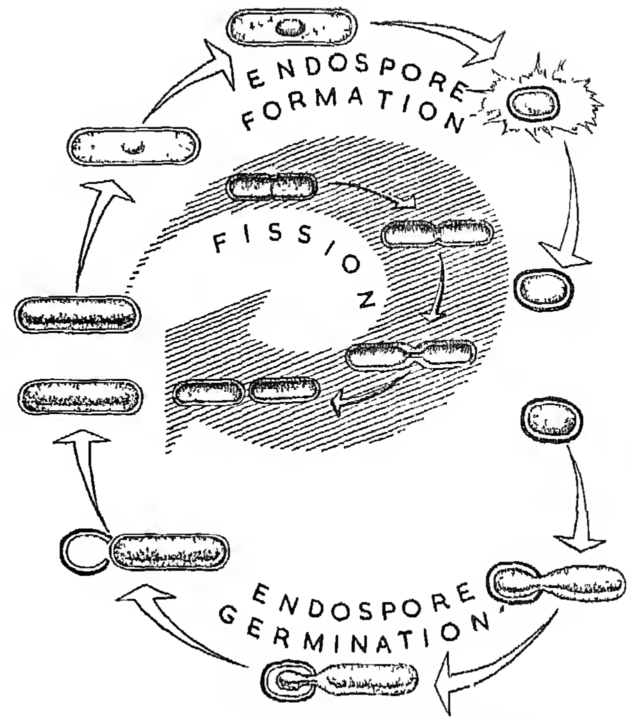


Fig. 19.2. Reproduction in bacteria. The usual mode of reproduction is fission. Endospores are formed occasionally and only in some forms.

Sterilization, Pasteurization and Preservation

It is a common experience that eatables, especially those with a high moisture content, start decaying in a few days This is because human food is also an excellent medium for the growth of microorganisms which are always present in the atmosphere, ever ready to help themselves under favourable conditions of temperature and moisture. To prevent early spoilage, foodstuffs should be kept as free from bacteria as possible and the bacteria already present should be prevented from multiplying. This is usually done by heating the material, and the process is known as **sterilization.** In general, heating a liquid to 60°C for half an hour is sufficient to kill most bacteria However, the spore forming bacteria are destroyed only when exposed to 120°C for 15 minutes. Sterilization is usually done by steam in a pressure cooker (or an autoclave) since steam under pressure is more effective than free-flowing steam

You are probably aware that the bottled milk sold in large cities is **pasteurized.** Pasteurization is a process of heating milk or other products to 62°C for 30 minutes. Although pasteurized milk is safe if kept in a refrigerator, it is not sterile since all the bacteria present in it have not been destroyed. If stored for a long period, pasteurized milk too will turn sour

Foods are also preserved by drying, or by adding salt or sugar These treatments are aimed at reducing the chances for the multiplication of microorganisms. The high content of sugar in a jam, for instance, serves

to 'suck' water from the invading bacterial cell by plasmolysis (*see* Chapter 38) Bacterial multiplication is also prevented or greatly reduced by a deficiency of water, and by low temperature as in a refrigerator or ice box. Figure 19 4 shows the temperatures at which common foodstuffs are preserved

Importance of Bacteria

To most people the word bacterium usually signifies harm and danger This is because the disease producing forms of bacteria have had a profound effect on human population However, it is less commonly realized that no more than one per cent of the bacterial species are harmful. Most of them are very beneficial In fact it would not be an exaggeration to say that the continuation of life on earth depends upon the activities of bacteria We shall now enumerate some of the useful as well as harmful aspects of bacteria.

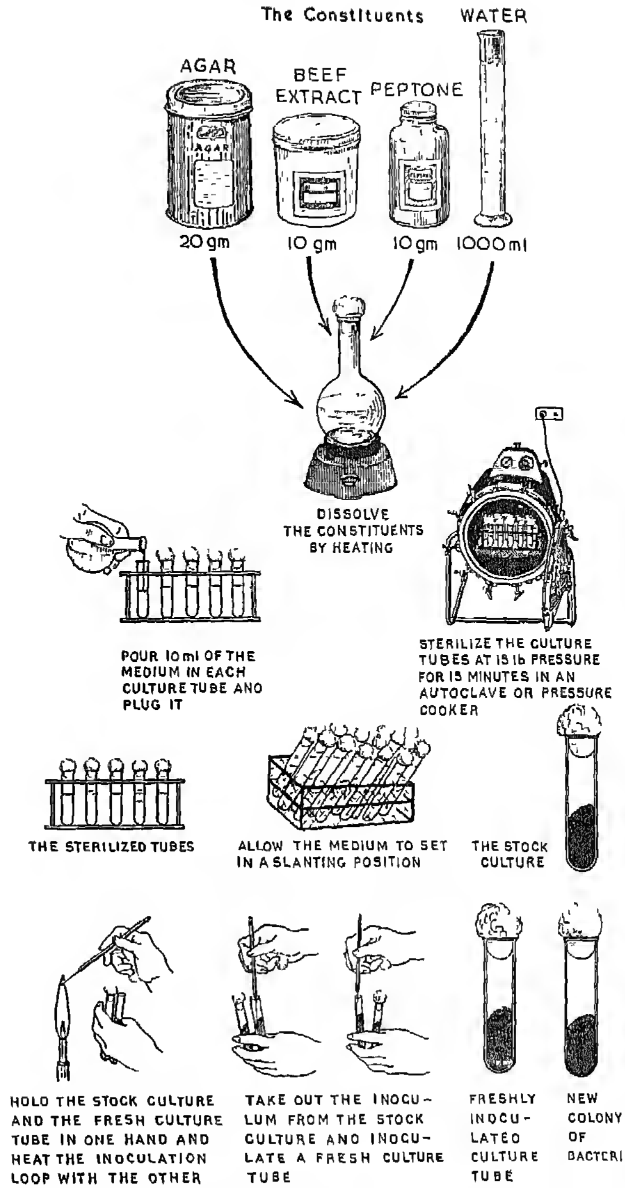


Fig 19.3. Steps in setting up bacterial cultures. Courtesy of the Department of Botany, University of Delhi

Bacteria decompose excretory products and dead remains of plants and animals into simpler substances Thus they clear the earth of its organic debris by putrefaction and decay. Putrefaction is the incomplete breakdown of the organic matter by the anaerobes, resulting in the formation of substances with offensive odours. Decay, on the other hand, is the complete decomposition by the aerobes without release of any evil smelling gases. The sewage disposal plants in big cities are all designed to encourage the activity of aerobic bacteria which destroy the

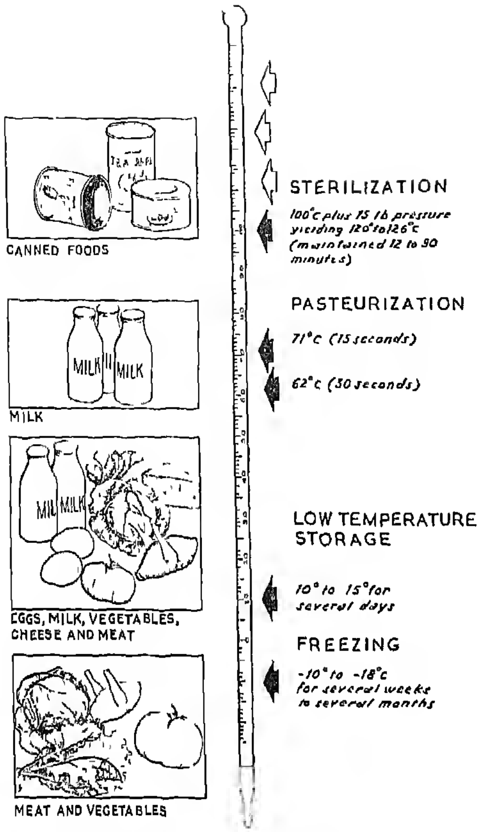
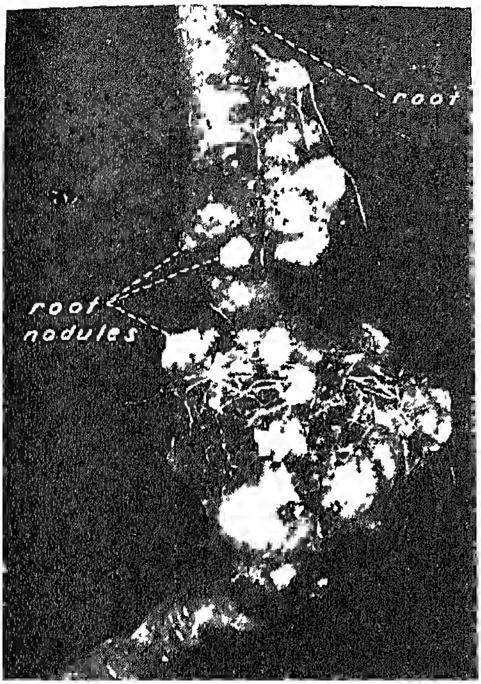


Fig. 19.4. Heat, cold and the prevention of spoilage. From *BSCS, Biological Science: An Inquiry into Life*, Harcourt Brace & World, Inc., New York, 1963

organic wastes rapidly. The importance of this vast group in nature will be better understood from the following facts. Every year the green plants convert about 200 billion tons of carbon from the atmospheric carbon dioxide into organic matter by the process of photosynthesis. If the amount of carbon were not replenished, the atmosphere would get exhausted of it within 30 years. Green plants can continue to live only if the carbon locked up in the dead organic matter is, in some way, released into the atmosphere in the form of carbon dioxide. The annual production of carbon dioxide due to the respiration of living organisms (both plants and animals) is only five per cent of the total carbon dioxide consumed by green plants. The remaining 95 per cent comes from the activities of microbes of which bacteria are the most important. It may be noted, however, that decay or decomposition is a complex process and is completed by the combined activities of several types of bacteria. Thus there are some which attack only carbohydrates and fats and convert them into carbon dioxide and water. Others attack proteins and convert them into simpler substances, sometimes even free nitrogen.

Together with other soil organisms, especially fungi, bacteria play a dominant role in maintaining soil fertility. The **ammonifying bacteria** convert the remains of dead plants and animals into ammonia which is transformed into ammonium compounds. This process is called ammonification. **Nitrite bacteria** now take over and convert the ammonium compounds into nitrites. The nitrites are then converted into nitrates by the **nitrate bacteria.** The availability of nitrates makes the soil fertile since green plants can use this form of nitrogen most efficiently.

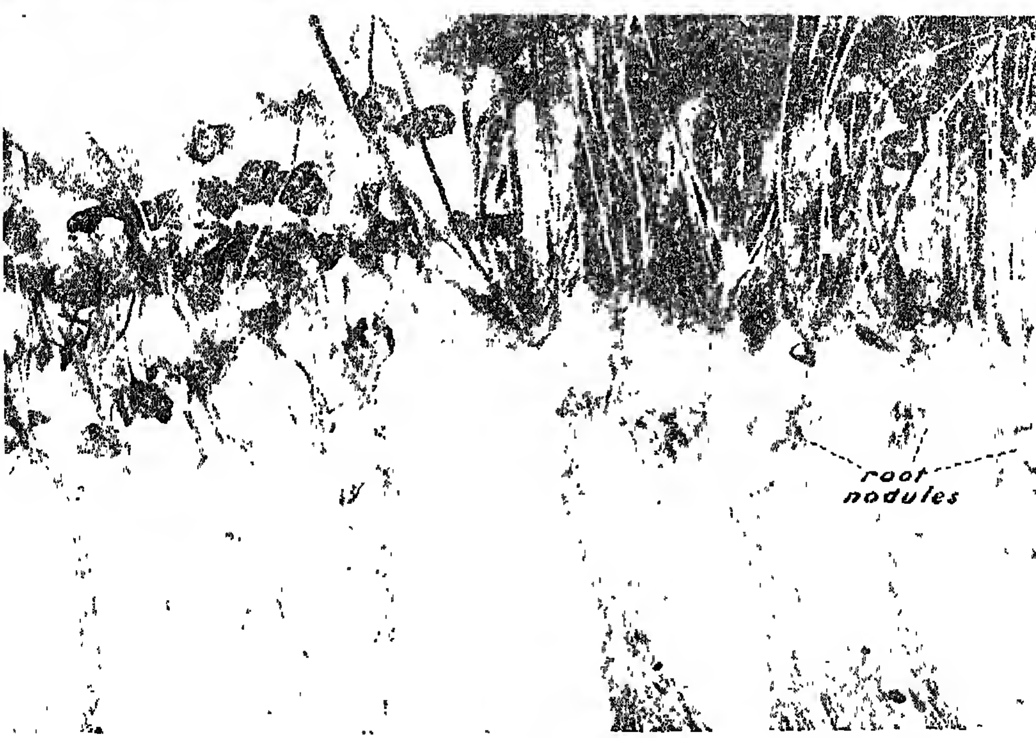
Certain bacteria are able to fix the free nitrogen of the atmosphere into nitrates. Species of *Rhizobium* are of particular interest in this connection. They are normally present in the soil and infect the root hairs of plants such as peas and groundnuts (legumes). They penetrate and proliferate in the cortical cells of the root. Abnormal growth of the root cells causes the formation of a swelling or nodule (Fig. 19.5). When this is crushed, a large number of rod-shaped bacteria can be observed. They live symbiotically in the roots obtaining their food from the root tissues of the plant while the latter receives the nitrates fixed by the rhizobia. Plants with nodules on their



roots are more robust than those lacking them (Fig 19 6) The exact significance of the bacteria in the nodules was revealed only a few decades ago, although it had long been known that the fertility of the soil could be maintained for a much longer time if crops with nodulated roots were grown alternately with cereals like wheat and barley

Fig. 19.5. ← **A root of** *Clitoria ternatea* **with nodules containing nitrogen fixing bacteria.** Courtesy of Bharati Chakrabarty, Department of Botany, University of Delhi

Fig. 19 6. ↓ **The effect of inoculation with root nodule bacteria upon the vegetative growth of** *Trifolium incarnatum* **On the left are the uninoculated plants, on the right, inoculated ones. Note how much larger the inoculated plants are than the uninoculated.** Courtesy of J C Burton, The Nitragin Company, Inc , Wisconsin



The digestive tracts of ruminating animals (sheep, cow, camel, etc.) consist of a number of compartments between the mouth and the stomach. The first one of these chambers, called the rumen, produces a slimy mass harbouring a large number of bacteria. When the half-chewed food enters this chamber, it is mixed with the bacteria-rich slime. The food is once again brought back (regurgitated) into the mouth and chewed thoroughly. During this process the bacteria break down the cellulose of the plant material into simple sugars which are readily absorbed by the animal body. A similar situation exists in the white ants which are able to 'eat' wood due to the presence of cellulose-breaking bacteria in their gut. The human intestine also harbours a large number of bacteria. Some of these make vitamins which become available to the host.

The sulphur bacteria convert hydrogen sulphide, a product of protein decay, into sulphuric acid. This becomes transformed into sulphates which are essential for plant growth. It is believed that the huge deposits of sulphur and iron ores found in some parts of the world have been formed by the activity of sulphur and iron bacteria respectively.

The manufacture of vinegar, curd, and cheese, the curing of tea, coffee and cocoa, the tanning of leather and separation of fibres from fibre plants such as hemp, flax and jute (Fig. 19.7) all involve the activity of bacteria. Some important industrial products such as lactic acid, citric acid, vitamins, acetone and alcohols

Fig. 19.7. Retting of jute stems to obtain fibres. Courtesy of the Press Information Bureau, New Delhi.

are also obtained as a result of bacterial activity

Whereas most bacteria carry on ammonification and nitrification, there are some which are busy doing the reverse, they transform the nitrates present in the soil into free nitrogen which escapes into the air. As a result of this, the soils become deficient in nitrogen. These denitrifying bacteria are anaerobic and occur most commonly in soils that are rich in moisture and proteinaceous matter.

VIRUSES

The viruses are so minute that they cannot be seen even with the most powerful light microscopes. They can be studied only with the help of an electron microscope. Many deadly human diseases such as smallpox, poliomyelitis, mumps, measles, yellow fever, influenza, and others result from virus infection. Certain diseases of plants, characterized by a mottling, rolling and wrinkling of leaves, are also caused by viruses.

The word virus (L. *virus*=a poisonous liquid) has long been in use to describe the poison of snakes but it acquired its present meaning only at the turn of the present century. The story of the discovery of viruses started in 1892 with a Russian scientist, Dmitrii Iwanowski. He was studying a disease of the tobacco plant characterized by a mosaic appearance of the leaves. He prepared an extract of the diseased plants and filtered it through a porcelain filter designed to remove all the bacteria. To his surprise Iwanowski found that this bacteria-free filtrate could still cause disease when inoculated into healthy plants. However, the significance of these results was not fully appreciated by him. Six years later Beijerinck, a Dutch botanist, repeated the same experiment and concluded that the cause of the tobacco mosaic disease must be some kind of a contagious fluid. He named it 'contagium vivum fluidum'. A few years later it was discovered that several diseases of animals and man were also due to similar substances.

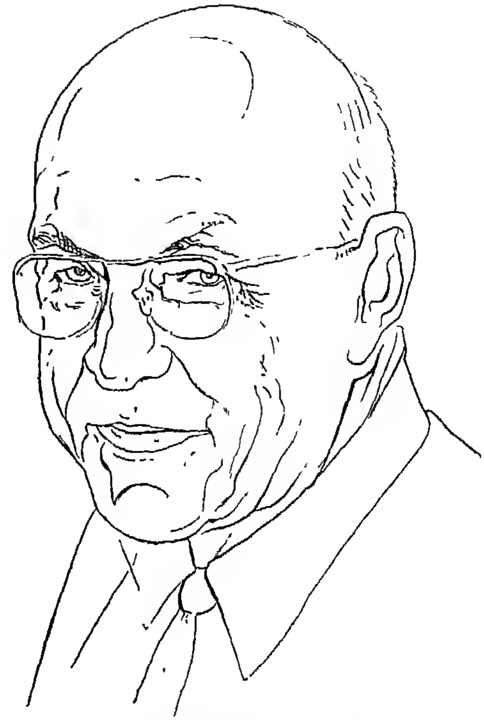


Fig. 19.8. W.M. Stanley (1904—), an American biochemist who obtained tobacco mosaic virus in a crystalline form in the year 1935, and won a Nobel Prize.

The most significant discovery came in the year 1935 when an American scientist, W.M. Stanley, succeeded in obtaining the tobacco mosaic virus in the form of definite crystals. He also demonstrated that these crystals were still capable of causing the disease in healthy plants. Subsequently several other viruses were crystallized.

The virus particles show a good range in shape. They may be spherical, hexagonal or rod-like. Their structure is very simple. There is just a core of nucleic acid (ribonucleic acid or deoxyribonucleic acid)

surrounded by a sheath of protein. There is no cytoplasm, nucleus or cell membrane. None of the viruses is known to be free-living. They grow and multiply only in the living cell. The question then arises: Are viruses to be considered living? They do possess two of the characteristics which we usually associate with living organisms, i.e. they can reproduce, and they undergo changes (mutations) in their hereditary characteristics. Thus if a virus particle is introduced in a suitable living cell, after some time a large number of virus particles can be detected in the cell. Yet, their reproduction is peculiar in that it can occur only within another living system. Outside a living system the virus is as dead as a stone—it neither respires nor reproduces. Virus crystals can be stored in bottles just like salt or sugar. At best we can regard them either as a link between the living and the non-living or as organisms that have become highly reduced.

Viruses spread mostly by contact. Insects, eelworms, aphids, beetles and leaf hoppers transfer them from diseased to healthy plants. Virus diseases of plants are controlled (a) by reducing the insect vectors, (b) by using varieties of plants resistant to a particular virus, and (c) by sowing disease-free seed.

The viruses causing cold and influenza spread by direct contact, spitting, or coughing. Polio virus is transmitted by way of infected faeces, flies being the probable carriers. Some of the human viruses can be combated by vaccination. In this process, a live but weakened virus is injected in the body. This causes the formation of antibodies that counteract the virus and thus make the individual immune. You can read about some important viral diseases of man in Chapter 56.

SUMMARY

Surrounding us, everywhere in air and soil, there are many microscopic unicellular organisms known as microbes. They come under four main groups: bacteria, rickettsiae, yeasts and protozoa. The protozoa are animals; the yeasts are fungi (plants without chlorophyll), the bacteria are the simplest and smallest of plants, and the rickettsiae may be called bacteria of still smaller size. The viruses are peculiar things sharing the properties of both living and non-living objects.

The bacteria are microscopic, single-celled plants usually lacking chlorophyll. They are either saprophytes or parasites. They possess distinct cell walls composed of proteins, and carbohydrates other than cellulose. Bacterial cells do not possess organized nuclei. However, they do have the essential nuclear material or chromatin. Bacteria multiply by simple fission. Excepting a few disease-causing forms, bacteria are very beneficial to human life. They are extremely valuable in sewage disposal, soil fertility and industry.

Viruses are even more minute than the bacteria. They can be seen only through an electron microscope. In the year 1935 W.M. Stanley succeeded in obtaining the tobacco mosaic virus in the form of definite crystals which were still capable of multiplying and causing the disease in healthy plants. Structurally a virus has just a core of nucleic acid surrounded by a protein sheath. Viruses grow and multiply only in living cells.

The spoilage of foodstuffs due to the growth of bacteria can be reduced by dehydration, pasteurization and sterilization, or by adding adequate quantities of salt or sugar.

QUESTIONS

1. How do viruses resemble the living and non-living objects?
2. Describe the structure of a bacterial cell. How does it differ from an ordinary plant cell (like the one you saw in an onion peel)?
3. What do you understand by decay? What is the importance of this process?
4. (a) What is the difference between pasteurization and sterilization?
   (b) Why do health officers advise the use of pasteurized milk?
   (c) Will the unpasteurized milk in a sealed bottle become sour? Pasteurized milk?
5. Why do we group bacteria among plants?
6. Account for the following:
   (a) Food keeps longer in cold storage than in an ordinary cupboard
   (b) Dried vegetables and fruits do not decay
   (c) Surgical instruments are boiled in water before using them for an operation.
7. Can you think of some place where bacteria may not be present?

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CHAPTER 20

Algae

THE algae commonly live in water, on damp soil, moist rocks, tree trunks and other similar habitats Some are restricted to special habitats like snow and the water of hot springs. Most algae are small plants which form the familiar green scum on the surface of ponds and on wet rocks. However, some marine algae, particularly the kelps, extend to a length of 100 metres or more. They are differentiated into stem-like and leaf-like structures superficially resembling those of higher plants

Many primitive algae reproduce simply by cell division. The daughter cells either separate immediately after division into independent individuals or remain joined into filaments or irregular masses Most of them, however, reproduce by asexual and sexual methods as well The commonest mode of asexual reproduction is by the formation of **zoospores.** These are one-celled structures, much smaller than the parent cells and swim about by the lashing movements of their flagella or cilia Each zoospore grows into a mature plant. Sexual reproduction takes place by the fusion of male and female gametes The resulting product is known as a zygote. Under unfavourable conditions the zygote remains dormant When favourable conditions return, it germinates to form one or more new plants We shall study two representatives of algae—*Chlamydomonas* and *Spirogyra*.

CHLAMYDOMONAS

Chlamydomonas is a widely distributed, unicellular, free-floating alga (Fig 20 1A) It occurs chiefly in ponds and ditches Quite often, it may be so plentiful as to colour the water bright green

The plant is a pear-shaped single cell with a cellulose wall Each individual has two flagella of equal length, arising close together at the pointed, colourless, upper end of the cell Below the base of the flagella there are two contractile vacuoles. They expand and contract alternately and are believed to expel the excretory products out of the cell. There is also a reddish dot-like organ or eyespot, placed laterally near the upper end In its broader region the cell has a single large, cup-shaped chloroplast (Fig. 20.1 A). In this is imbedded a round proteinaceous body known as the **pyrenoid.** This is concerned with the formation of starch in the cell The nucleus is suspended in the cytoplasm in the hollow of the chloroplast cup.

The pear-shaped cells move about by the lashing movements of their flagella The movement is automatic but it is considerably

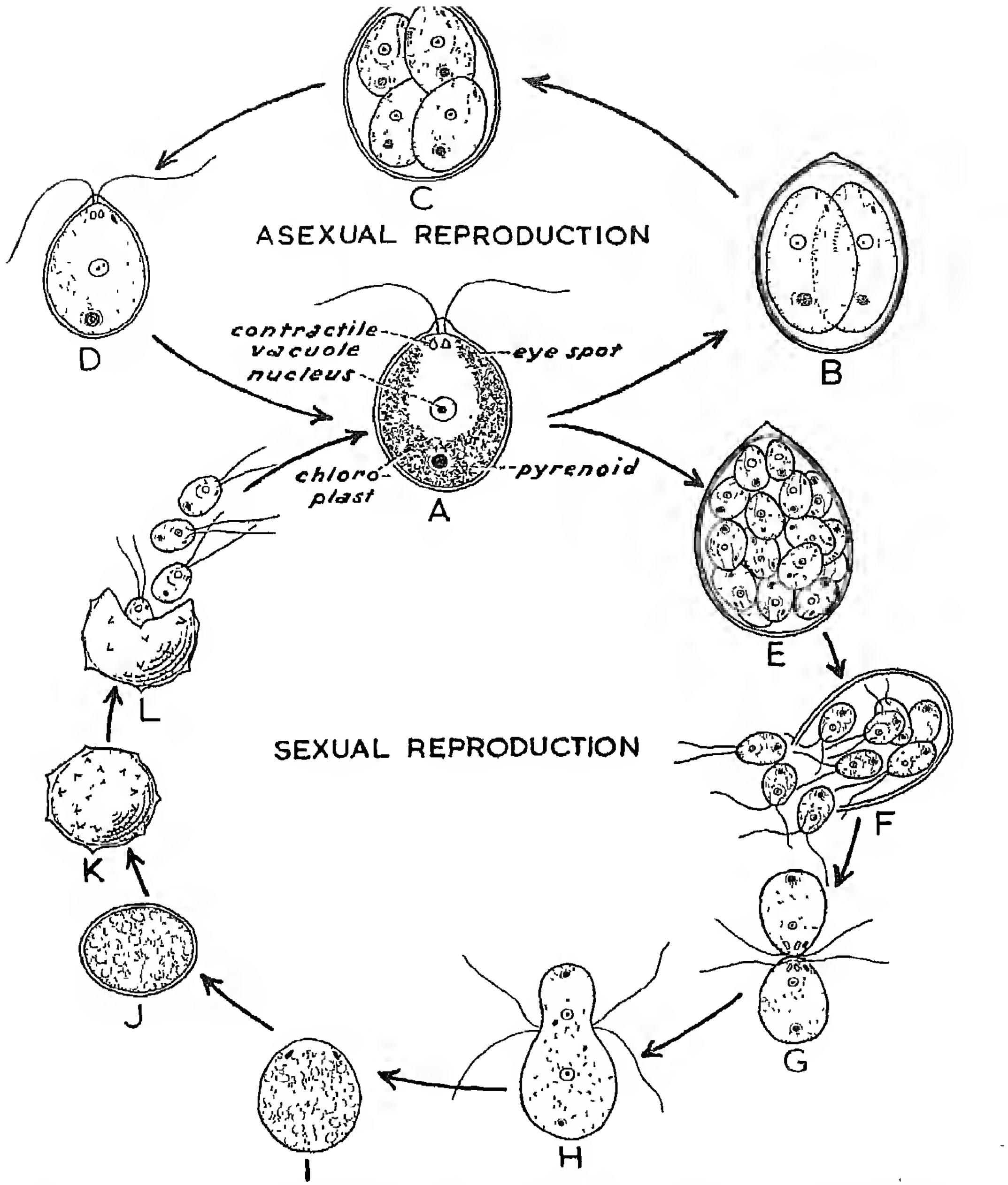

Fig. 20.1. Chart illustrating the main features of the structure and life cycle of *Chlamydomonas.* **A. An adult individual. B and C. Formation of two and four zoospores from the protoplasm of a parent cell. D. Young zoospore; this would gradually grow into an adult plant. E. Formation of a large number of gametes in the parent cell which has shed its flagella. F. The wall cf the parent cell has burst, setting free the gametes. G and H. Fusion of gametes by their anterior ends. I and J. Fusion of the gametes to form a zygote. K. The zygote with its thick wall in surface view; the wall enables the zygote to withstand adverse conditions. L. Germination of zygote; note the zoospores escaping from the parent cell.** Courtesy of the Department of Botany, University of Delhi

influenced by external stimuli. For instance, the cell tends to move towards diffuse light and away from intense light The eyespot is believed to be the site of perception of the stimulus.

Asexual reproduction takes place by means of zoospores At the time of their formation, the plants shed their flagella and come to rest The protoplasm divides into two, four or eight uninucleate portions (Fig 20 1 B and C) These protoplasmic bits resemble the parent cell except in being much smaller. They develop their own flagella and are liberated by the rupture of the parent cell wall. The liberated zoospores (Fig. 20.1 D) now grow to become mature individuals.

Sexual reproduction occurs by the formation of gametes They are formed in the same way as the zoospores but are of a smaller size since sixteen, thirty-two or even sixty-four of them are formed by a single individual (Fig. 20.1 E) They are set free by the rupture of the parent cell wall (Fig. 20.1 F). Two gametes, usually from different individuals, meet by their anterior ends (Fig. 20 1 G and H) They cast off their flagella and the contents fuse to form a zygote (Fig. 20.1 I and J).

The zygote (Fig. 20 1 K) is resistant to adverse conditions like high or low temperature, lack of moisture, etc It enables the alga to survive periods of drought and heat. Under favourable conditions, it germinates to form four zoospores which become mature plants after some time (Fig. 20 1 L).

Chlamydomonas is one of the simplest plants In some respects it resembles *Euglena* (*see* Chapter 7). The common features are the presence of flagella, contractile vacuoles and an eyespot.

SPIROGYRA

Spirogyra is one of the commonest of the green algae in fresh water ponds It is more elaborate than *Chlamydomonas* and consists of long unbranched threads or filaments. These are usually seen as dark green masses floating on the surface of water in ponds and slow moving streams The mass is slimy to touch This is because the filaments are covered with a mucilaginous sheath

If you examine a filament under the microscope, you will find that it is made of a single row of cells which are longer than broad Each cell has a large central vacuole and a peripheral layer of cytoplasm (Fig 20.2). The most conspicuous parts of the cells are the chloroplasts There may be one, two or even more of them in each cell. A chloroplast of *Spirogyra* is like a long ribbon set in the form of a spiral. The plant derives its name from this peculiar shape of the chloroplast A number of large pyrenoids are imbedded in the chloroplast. The nucleus is suspended in the centre of the cell by means of cytoplasmic strands

The cells of a filament are all alike in structure and function Any cell may divide and add to the length of the filament Vegetative reproduction occurs by breaking up of filaments into smaller fragments Each one of these then grows into a new filament

Sexual reproduction takes place by conjugation. In this process two filaments come to lie very close to each other (Fig. 20.3 A) Small protuberances then grow from the cells of both Protuberances from cells lying opposite each other come in contact (Fig 20 3 B). The walls between them get dissolved, resulting in a canal that connects the two cells (Fig. 20.3 C). While this is going on, the protoplasm of each conjugating cell rounds up into a gamete (Fig. 20.3 C). A gamete from one of the cells now wriggles through the canal into the opposite cell. There it fuses with the other gamete and a zygospore is formed (Fig. 20 3 D) The

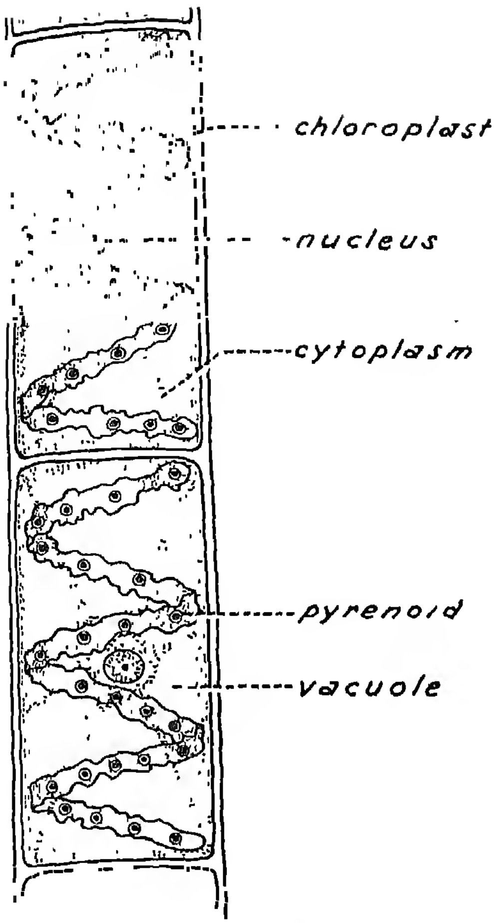

Fig. 20.2. Part of a filament of *Spirogyra* Courtesy of the Department of Botany, University of Delhi.

gamete which moves is considered male while the passive or stationary gamete is regarded female.

The zygospores of *Spirogyra* are globular or ellipsoidal (Fig 20.3 E). They develop a thick wall and can withstand adverse conditions. At the time of germination the zygospore nucleus divides meiotically to form four nuclei (Fig 20.3 F), each of which now contains half the number of chromosomes. Three of these nuclei degenerate (Fig 20 3 G) The zygospore wall cracks and a small tube or germling emerges from it (Fig. 20 3 H) It divides transversely to produce a mature filament.

Economic Importance

The algae are of great value to man and animals in many ways. They are the chief food of fish and some other aquatic animals Even the carnivorous animals like whales depend, in the last analysis, on algae since the smaller animals on which they feed all subsist on algae It might surprise you to know that the total food production by marine algae is at least eight times that by the land plants Algae also maintain a proper balance of carbon dioxide and oxygen in the water. In the presence of light they use up the carbon dioxide exhaled by aquatic animals and release oxygen which is used by the animals in respiration The algae too need oxygen for respiration but the rate of photosynthesis is much higher than the rate of respiration, so that enough oxygen is left over for the use of animals. Oxygen also promotes the activities of the aerobic bacteria that decompose dead organic matter in water. Thus, by their activity algae keep the water clean for the continued living of the fish and other animals Algae are sometimes used in sewage tanks to purify the contaminated water

There is a great deal of anxiety these days for providing an adequate food supply to the underfed and increasing human population of the world. It is felt that besides the conventional fields on land, we may have to raise new crops in water The aquatic, unicellular, green alga *Chlorella*, similar in many respects to *Chlamydomonas*, appears to be quite promising in this respect. Although somewhat unpalatable, it is rich in protein and can be cultured easily. In future it may be possible to make it acceptable to man and domestic animals as a

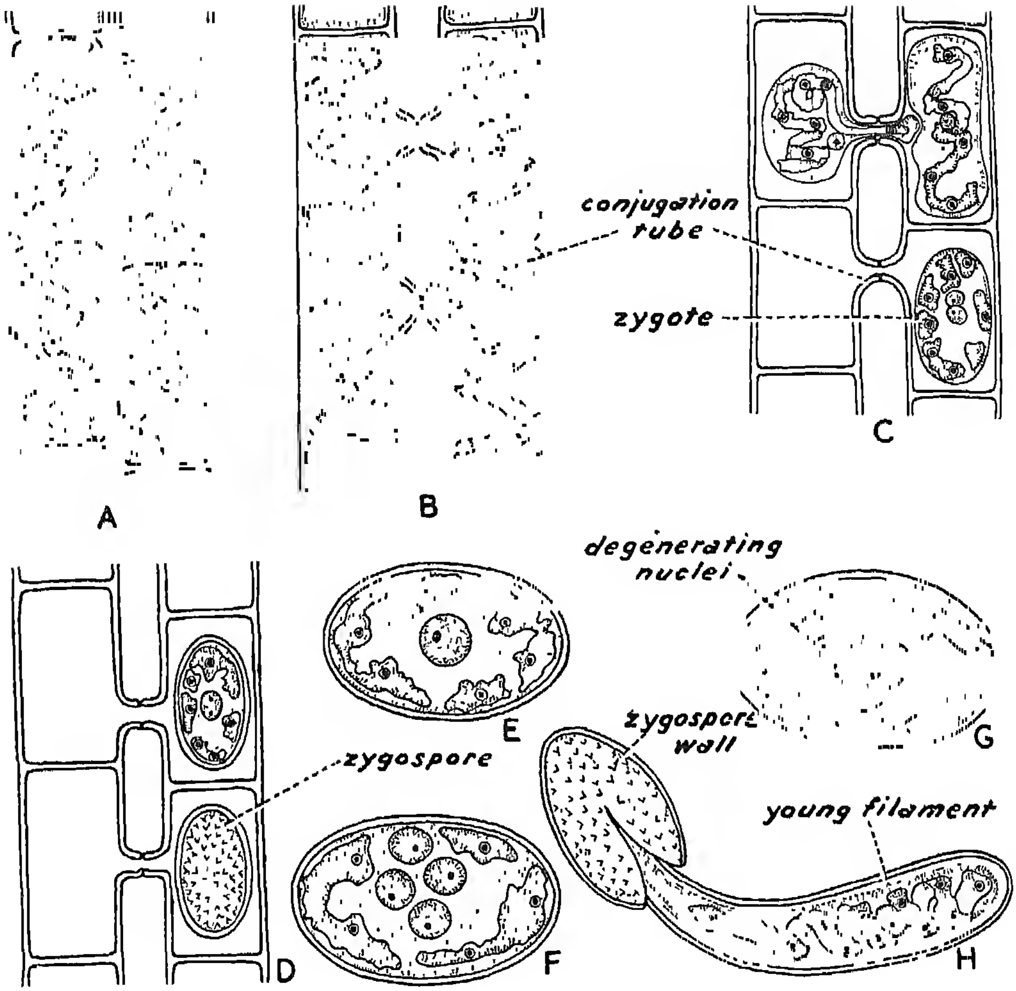

Fig. 20.3. Sexual reproduction in *Spirogyra* A. Two filaments lying close together. B. The formation of papillate protuberances from the opposite cells. C. The formation of a conjugation tube and the migration of the male gamete; in the lower cell conjugation is already completed. D. The fusion of gametes and the formation of a zygospore. E. Liberated zygospore. F. Four nuclei formed as a result of the meiotic division of the zygospore nucleus. G. Degeneration of three out of the four nuclei. H. Germination of the zygospore, the wall has cracked and a young filament has emerged.
Courtesy of the Department of Botany, University of Delhi

source of food to supplement our inadequate resources.

Blue-green algae are able to fix atmospheric nitrogen in the form of nitrates and ammonium compounds and thus add to the fertility of the soil. Algae growing in water-logged rice fields are helpful in this way. It is also claimed that 'usar' lands

(alkaline soils) can be reclaimed by encouraging the growth of blue-green algae on them On the other hand, some algal forms are known to contaminate the municipal water supplies. They produce oily substances which impart a foul smell to the water. In exceptional cases, the water may even become poisonous. The algal growths may be controlled by treating the water reservoirs with a dilute solution of copper sulphate

The unicellular marine diatoms that lived in the remote past, have left their remains in the form of enormous deposits of diatomaceous earth. This is a whitish substance, comprising empty cell walls impregnated with silica Being extremely hard, it is used as an abrasive ingredient in toothpastes and polishes, and for several other purposes in industry.

Certain red algae such as *Gracilaria* and *Gelidium* yield a gelatinous substance known as agar-agar This is used as a stabilizing agent in ice creams and many other preparations. It is also used for the preparation of culture media in biological laboratories Some other seaweeds yield a mucilaginous product, algin, which is being increasingly used in the production of plastics and artificial fibres. In China and Japan, some seaweeds (kelps) are regularly harvested for use as food for man and cattle. The ash obtained by burning the kelps is a valuable source of iodine and potassium.

SUMMARY

The algae are photosynthetic thallophytes commonly thriving in moist or aquatic situations Some grow in the oceans and may reach a length of over 100 metres. Such forms even possess stem-like, leaf-like and root-like organs.

Vegetative reproduction is very common in the algae enabling them to multiply quickly and cover large areas of water in a short period Algae also reproduce asexually by means of unicellular spores and zoospores Sexual reproduction is also prevalent.

Chlamydomonas is a unicellular green alga found in ponds. The pear-shaped cells swim about by means of a pair of flagella. Other structures found in it are a cup-shaped chloroplast, contractile vacuoles, a pyrenoid, a nucleus, an eyespot, and cytoplasm. *Chlamydomonas* reproduces asexually by means of zoospores and sexually by motile gametes.

Spirogyra is an unbranched filamentous alga found as green tufts floating in ponds. Its cells have conspicuous chloroplasts in the form of spiral bands Sexual reproduction in *Spirogyra* involves conjugation of two filaments The zygospore formed by the fusion of the two gametes secretes a thick wall around itself and can withstand dry conditions.

The economic importance of algae can be judged by the fact that about 90 per cent of the total photosynthesis of the world is carried on by algae. *Chlorella*, a unicellular alga with a high protein content, may be an answer to the problem of our diminishing food supply.

QUESTIONS

1 It is estimated that nine-tenths of all the photosynthesis in the world is carried out by the algae Does it benefit human beings, and if so, how?

2. No algae are found at depths greater than 250 metres in the sea Suggest a possible explanation. Would you expect any other types of plants to live there?

3 What is the difference between a spore and a zoospore?

4. Compare the modes of sexual reproduction in *Chlamydomonas* and *Spirogyra*

5 Draw a diagram of a transverse section of a cell of *Spirogyra* and of *Chlamydomonas*.

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CHAPTER 21

Fungi

ALTHOUGH the word fungus (plural, fungi) means a mushroom, it includes many other types as well Thus the ringworm that disfigures the skin, the mould that grows on bread and jam, the 'scum' that ferments wine, the 'rust' which makes the wheat plants look red, the puffballs that spring up on the heaps of manure, the 'shelves' or 'brackets' that emerge from the trunks of forest trees—are all fungi The body of most fungi is made of slender, thread-like filaments known as hyphae. A mat of hyphae is called a mycelium

Fungi can be easily distinguished from algae by the complete absence of chlorophyll. Consequently, they cannot make their own food They are **heterotrophic,** i.e they obtain their food, as we do, from external sources A fungus is parasitic if it obtains food from a living plant or animal It is said to be saprophytic if it depends for its nutrition on the dead remains of plants, animals and their waste products The fungi produce organic catalysts or enzymes in order to obtain their food from the living host or from dead organic material. Like other living organisms, they require food for their metabolism, growth and reproduction The surplus food is stored in the mycelium as carbohydrates, fats and proteins

Some fungi live in association with certain algae to form a lichen. The fungus makes the bulk of the lichen thallus and the alga remains buried within it The two partners live in a state of symbiosis or a life of mutual benefit. The fungal partner obtains its food from the alga while the latter, being enclosed in the thallus, remains well protected Similarly, certain fungi live symbiotically within the roots of forest trees. This kind of association is termed **mycorrhiza.**

Most fungi reproduce by vegetative as well as asexual and sexual methods. They usually produce enormous numbers of minute reproductive cells or spores The spores are widely dispersed by wind, water, insects and man. They are so constantly present in the air that a moist piece of bread exposed to it becomes mouldy because the spores fall on it and germinate to form a thick mat of hyphae. We shall now study two representatives of this great group of plants. The first, *Rhizopus,* is a saprophyte; the second, *Puccinia,* is a parasite

RHIZOPUS

The bread mould, *Rhizopus,* is commonly found on moist, exposed foodstuffs and the dung of animals It is also known as black mould due to the black colour of its spore sacs.

Expose a piece of moist bread to air and cover it with a bell-jar to keep it in a moist

condition (Fig. 21.1). After a few days, a dense cottony or fluffy growth of *Rhizopus* appears on the bread. This growth is the mycelium of the fungus On careful examination, you will find tiny black dots scattered all over its surface These are the sporangia or spore sacs and inside them occur the spores

If a bit of the mycelium with some sporangia is examined under the microscope, it is found to consist of a dense mass of intertwined hyphae. At intervals the creeping hyphae produce bunches of fine threads or rhizoids which penetrate into the bread and absorb the food material (Fig. 21 2 A). The hyphae also produce clusters of erect branches opposite the rhizoids. Each erect hypha or **sporangiophore** bears a **sporangium** at its free end (Fig. 21 2 A). The sporangium has a sterile dome-shaped region near its base (Fig 21.2 B, C and D) At maturity the sporangia become black. They are filled with numerous small, dark-brown spores The sporangial wall flakes off to liberate the spores which are carried away to long distances by air currents If suitable conditions of moisture and warmth are available a spore germinates to produce a hypha (Fig. 21.2 E and F) that branches profusely to form a new mycelium

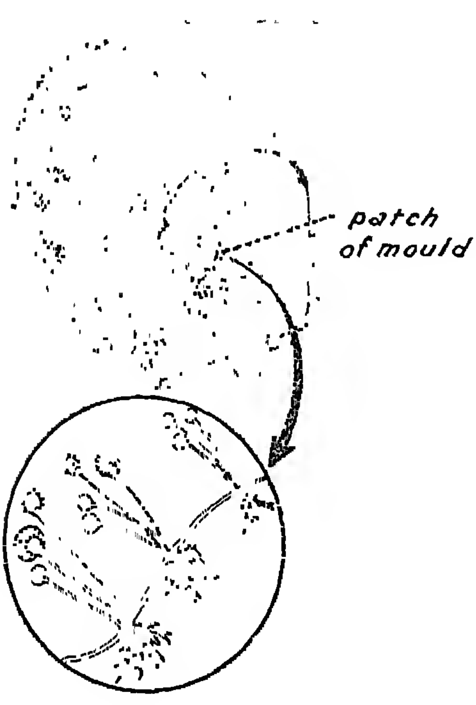

Fig. 21.1. A piece of moist bread turned mouldy due to the growth of *Rhizopus* and other fungi. Courtesy of the Department of Botany, University of Delhi.

As in *Spirogyra*, sexual reproduction in *Rhizopus* takes place by the conjugation of two filaments These are similar in shape but have different sexuality Accordingly, they are termed plus and minus strains. They are produced on the tips of two short branches arising on different hyphae The terminal parts of two branches come in contact and become slightly swollen (Fig. 21.2 G and H) They contain several nuclei and dense cytoplasm and become separated as **gametangia** by means of a cross wall (Fig. 21.2 I) When the gametangia are mature, the walls between them dissolve and the contents become mixed (Fig. 21 2 J) The plus and minus nuclei of the two gametangia fuse in pairs The number of chromosomes in each nucleus is, therefore, doubled. The two gametangia thus fuse to form a single multinucleate body, called the zygospore, which then enlarges and secretes a dark, thick, warty wall around itself (Fig 21 2 K). This can stand adverse conditions of heat and dryness which the mycelium itself is unable to survive. When favourable conditions return, the zygospore germinates forming an erect hypha which bears a sporangium at its tip (Fig. 21.2 L). During the formation of the spores the number of chromosomes in each nucleus is again reduced to half At maturity, the wall of the sporangium ruptures

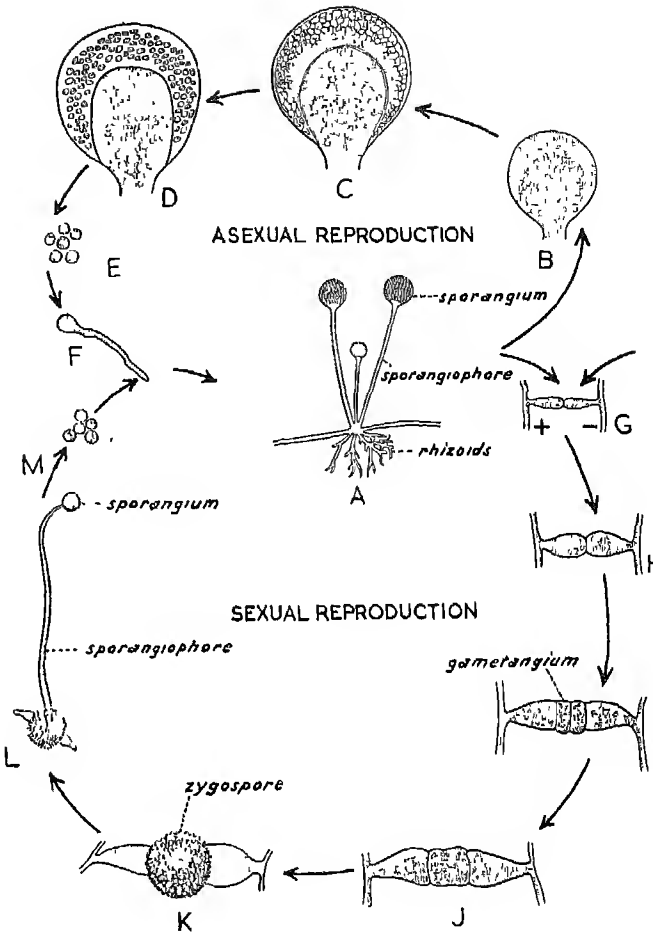

Fig. 21.2. Structure and reproduction of *Rhizopus* A. Part of the mycelium enlarged to show the creeping hypha, rhizoids and sporangiophores. B, C and D. Stages in the development of a sporangium. E. Spores F. Germinating spore. G and H. Conjugation of the gametangia of plus and minus strains. I. Formation of cross walls separating the gametangia from the suspensors. J. Dissolution of the contact walls of the two gametangia and mixing of their contents. K. The multinucleate body formed by the fusion of the two gametangia secretes a thick, warty wall and becomes a zygospore. L. Germination of a zygospore. M. Spores. Courtesy of the Department of Botany, University of Delhi.

to liberate spores (Fig 21.2 M). As usual, the spores germinate and form mycelia

PUCCINIA

Puccinia graminis is popularly known as the rust fungus since it produces masses of reddish-brown spores on the infected plants which look rusted. If you happen to visit wheat fields in the plains in the months of February and March, sometimes the entire field wears a rusty brown appearance. This is because of severe infection by *Puccinia* which is a destructive parasite of wheat and barley throughout the world. The fungus not only robs the plants of their food but also considerably reduces their green surface and thus interferes with the further production of food by leaves The mycelium of the fungus occurs mostly in between the cells of the leaves and the stem However, some hyphae penetrate the cells to absorb nourishment and function as haustoria (L *haurire*=to drink).

The hyphae produce characteristic reddish-brown blisters or **pustules** on the surface of the stems and leaves (Fig 21.3 A, B and C) If you examine a pustule with a lens, you will find a powdery mass of spores surrounded

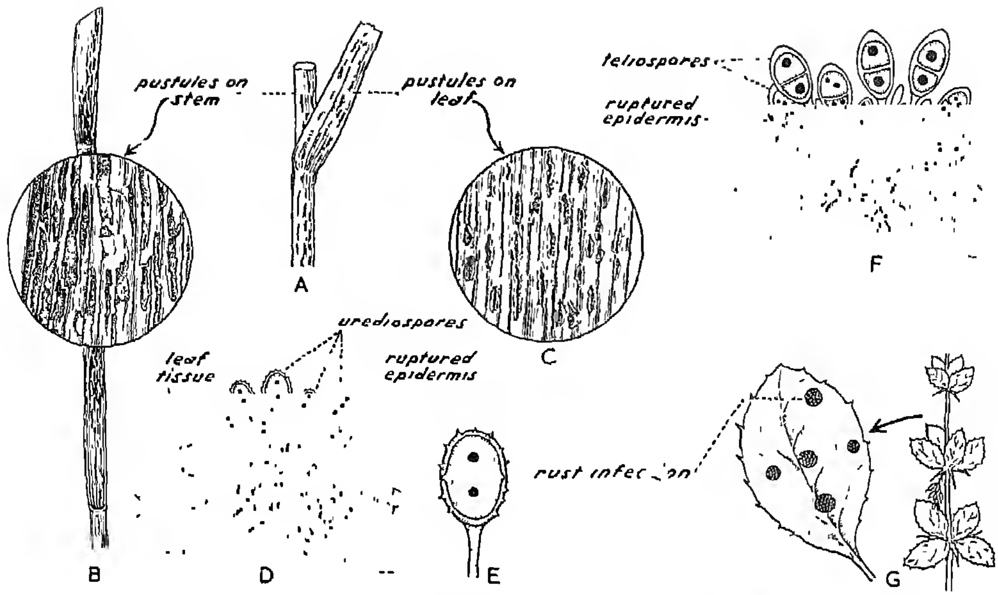

Fig. 21.3. *Puccinia graminis* **A. Portion of a heavily infected stem and leaf of a wheat plant. B. The pustules on the stem enlarged to show the spore masses and ruptured epidermis. C. The pustules on the leaf enlarged. D. Vertical section of a leaf passing through the pustule containing urediospores. E. Urediospore enlarged. F. Vertical section of a leaf passing through a rust pustule containing teliospores. G. Infected leaves of barberry plant.** Courtesy of the Department of Botany, University of Delhi

by the ruptured epidermis of the stem or leaf. When examined under the microscope, the spore is seen as an oval cell borne on a long stalk (Fig 21 3 D and E). The individual spores are orange-coloured. The body of the spore has a thick spiny wall and contains two nuclei (Fig. 21.3 E) Such spores are known as **urediospores.** They are formed early in the season and are blown by wind currents If they happen to fall on other wheat plants, they infect them too. The characteristic rust pustules appear on the newly infected wheat plants after about two weeks Thus, if conditions are favourable for spore dispersal and germination the disease spreads rapidly from plant to plant. Later in the season the pustules produce another kind of spore known as **teliospore** (Fig. 21.3 F) The colour of the pustule then changes from reddish-brown to black Like the urediospores, the teliospores are also stalked, but unlike them, they are black, two-celled and have very thick walls Each cell of the teliospore has two nuclei to start with but they soon fuse and the cells of the mature teliospore become uninucleate Being thick-walled, the teliospores are resistant to adverse weather conditions They cannot infect the wheat plant but can readily attack a different plant—barberry (Fig. 21.3 G)—on which the rest of the cycle of the fungus is completed. After passing the later part of its life on barberry, the fungus again migrates to wheat plants. Thus *Puccinia graminis* alternately infects two different hosts, wheat and barberry. The uredio- and teliospores are produced on a cereal crop like wheat while the other types of spores are formed on barberry. Efforts have been made in some countries

to control the wheat rust by destroying the alternate host—barberry. The object of this campaign is to eradicate the rust by interrupting its life cycle However, in India the barberry plant does not play any significant role. It is the urediospore stage which survives in the hills on out-of-season wheat plants The urediospores from such infected stray plants are blown down every year to the wheat crop in the plains The only effective way to avoid rust infections is to use disease resistant varieties The Indian Agricultural Research Institute at New Delhi has produced some wheats of this kind

Economic Importance

The fungi influence our life in many ways The parasitic forms cause serious diseases in crop plants, and have even brought about important changes in the history of some countries In Ireland, for instance, the late blight fungus completely destroyed the potato crop during 1845-47. Since potato was the staple food of the Irish people, they were compelled to migrate in millions to the USA. A severe famine broke out in Bengal in 1942-43 due to the destruction of the rice crop by a fungus called *Helminthosporium* Fungi also cause serious skin and lung infections in man and domestic animals. Many saprophytic fungi are responsible for the spoilage of our foodstuffs, leather goods, and textiles.

However, the fungi are not always detrimental to man's welfare A good many are highly useful Together with the saprophytic bacteria they act as natural scavengers They decompose the dead bodies of plants, animals and their waste products. The simpler products of decomposition then escape into the air and soil. The soil thus becomes enriched and maintains its fertility

Fungi also provide an important source of many valuable chemicals used in medicine and industry Such chemicals include alcohols, enzymes, organic acids and many life-saving drugs. The truffles, morels and mushrooms provide a delicate, palatable food

Economically, yeasts are perhaps the most important group of fungi From times immemorial, they have been used in the manufacture of wine and baked bread They ferment sugars into alcohol with the liberation of carbon dioxide. Some varieties of yeast are used in the manufacture of bread When added to dough, they ferment the traces of sugar present in it into carbon dioxide and alcohol, and make the dough 'rise' When the bread is baked, alcohol and carbon dioxide escape from the loaf, making it light and spongy. Yeasts are also used for the manufacture of vitamins They are often made into pills to supplement the diet since they are rich in essential nutrients including vitamins

One of the most important of the fungi is *Penicillium*, the blue-green mould (Fig 21.4) It is the source of the well-known penicillin, which is effective in destroying many kinds of pathogenic bacteria This

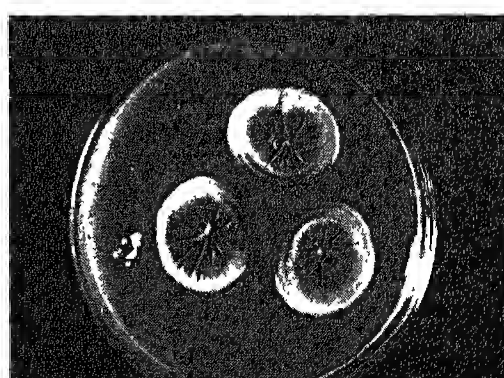

Fig. 21.4. Colonies of *Penicillium* It is from a species of this fungus that the 'wonder drug'—penicillin is extracted. Courtesy of the Press Information Bureau, New Delhi.

drug is an **antibiotic**—a substance derived from one organism and capable of inhibiting the growth of another. You will read about the fascinating story of the chance discovery of penicillin in Chapter 58

Another fungus, *Claviceps* or ergot, attacks the grains of barley and rye and replaces them with blackish horn-like fungal bodies full of hyphae. These contain a poisonous substance which causes a constriction of blood capillaries and proves fatal if taken in large quantities However, in proper doses it is most useful since it may stop the bleeding resulting from an accidental rupturing of blood vessels.

SUMMARY

Fungi are non-green plants and include such forms as mushrooms, moulds, rusts and puffballs The bodies of most fungi are made up of slender, thread-like filaments known as hyphae A mass of hyphae is called a mycelium. Fungi are heterotrophic, i.e. they cannot make their own food. They may have a parasitic or saprophytic mode of nutrition Some of them also live in association with algae to form lichens. Fungi may reproduce by vegetative, asexual, or sexual means.

Rhizopus is an example of a saprophytic fungus, which commonly grows on bread. Its mycelium bears numerous sporangia which give rise to spores The spores germinate to form hyphae. Sexual reproduction takes place by the conjugation of two gametangia which come from two different types of mycelia—plus and minus. The zygospore germinates to form another sporangium.

Puccinia is an example of a parasitic fungus The species, *P graminis*, is very destructive and has a complicated life cycle which is completed on two hosts, wheat and barberry It produces many types of spores. Of these, the urediospores and teliospores are produced on wheat.

Fungi are our friends as well as foes Together with bacteria they help in decay and decomposition They yield valuable antibiotics and many other industrial products. On the other hand, they also produce serious diseases of crop plants and human beings

QUESTIONS

1 Is the fungal partner in a lichen parasitic or symbiotic? Give reasons for your answer.

2. Give four methods by which foodstuffs may be protected from the attack of moulds.

3 People who manufacture jaggery boil the cane juice as soon as it is extracted. Why is it not advisable to store the juice before processing?

4 Which mode of life is more advantageous to the fungus—parasitic or saprophytic?

5 Devise a method to detect the presence of fungal spores in the air

6. Compare the mode of sexual reproduction of *Rhizopus* with that of *Spirogyra*.

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CHAPTER 22

Bryophyta

BRYOPHYTES (Gk *bryon*=moss, *phyton* =plant) are small plants that lack roots, flowers and seeds. Most of them (all mosses, and many liverworts) have small stems bearing tiny leaves Others have a forked thallus-like body. They are attached to the soil by means of tiny thread-like structures called rhizoids The plant body is made of simple parenchymatous tissue. Due to the lack of water-conducting tissues they never attain any great size, being usually less than 15 centimetres in height They are very common in moist shady places, especially after a few showers of rain They can also be found in the winter near the banks of rivers, water reservoirs, streams, and in garden beds. Two important features immediately separate them from the thallophytes First, their sex cells or gametes are produced in special bodies which have a jacket of protective cells. Secondly, they produce distinct embryos. We shall study two members, *Riccia* and moss, to illustrate the general pattern of life cycle in this group of plants

RICCIA

Riccia is a common liverwort which occurs as green circular patches on moist ground (Fig. 22 1 A). Each patch consists of a number of forking, ribbon-like plants attached to the soil by hair-like rhizoids Since it lacks stem, roots and leaves, its body is described as a thallus.

If you examine the upper or dorsal surface of the thallus with a lens, you will find numerous small pores and a depression or furrow in the middle (Fig. 22.1 B). The lower or the ventral surface bears numerous rhizoids and tiny brown scales which perhaps serve to store water

The structure of the plant body can be studied from a transverse section of the thallus (Fig 22.1 C and D) It is roughly divisible into two regions—the upper and the lower The upper region is made up of vertical rows or filaments of green cells Each row terminates in a distinct epidermal cell The vertical spaces between the filaments are the air canals (Fig 22.1 D) The pores on the dorsal surface of the thallus are the openings of these air canals. The lower part of the thallus is made up of thin-walled, colourless cells which store the food material manufactured in the upper region of the thallus. The rhizoids arise by the elongation of certain cells in the lower epidermis.

The plants may multiply either by the vegetative or the sexual method In vegetative reproduction the lobes of the thallus become separated due to the death of the

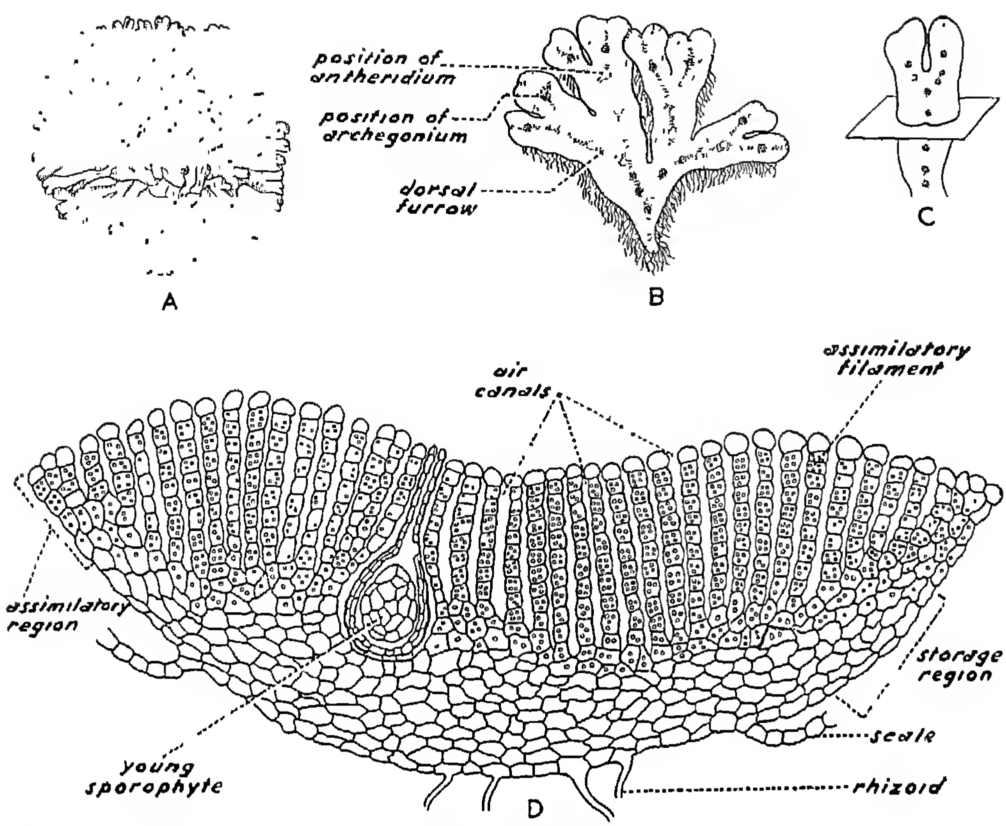

Fig. 22.1. Structure of *Riccia* A. Thalli growing together in the form of a rosette. B. Single thallus enlarged to show the dorsal furrow and the position of sex organs. C. Plane of the section drawn in the next diagram. D. Transverse section of the thallus showing the upper assimilatory region and the lower storage region. A to C, Courtesy of the Department of Botany, University of Delhi D, from G M. Smith, *Cryptogamic Botany*, Vol II, McGraw-Hill Book Company, New York, 1938

older part The separated lobes grow into new plants

Sexual reproduction is equally common The male and female sex organs, known as **antheridia** and **archegonia** respectively, occur at the base of the central groove of the thallus. They are enclosed singly in small chambers which open to the outside by small pores. Each antheridium is a stalked, globose or pear-shaped body, having a protective jacket or wall (Fig 22.2 A) It produces numerous **antherozoids** (the male gametes) each bearing two long flagella (Fig 22 2 B) When the antheridium is mature, its apex disorganises and the antherozoids are liberated into the outer chamber from where they swim out.

An archegonium is a flask-shaped body, with a short stalk and a long neck partly projecting above the surface of the thallus (Fig. 22.2 C). It contains the female gamete or the egg cell in its broader basal

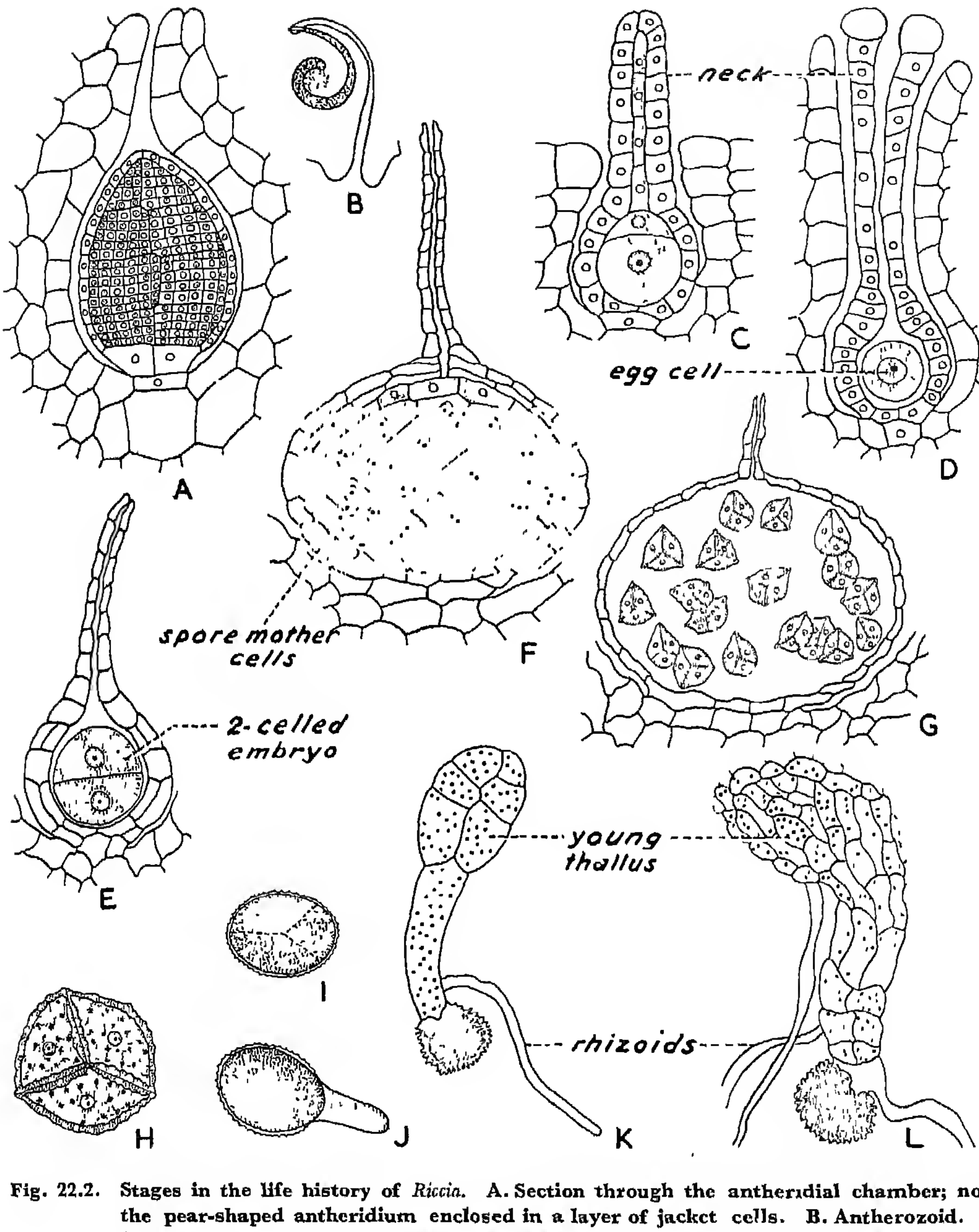

Fig. 22.2. **Stages in the life history of *Riccia*. A. Section through the antheridial chamber; note the pear-shaped antheridium enclosed in a layer of jacket cells. B. Antherozoid. C. Longitudinal section of a mature archegonium with its neck projecting above the thallus. D. Longitudinal section of an archegonium ready for fertilization; the cells in the neck canal have disorganized. E. First division of the zygote. F. Longitudinal section of a young sporophyte. G. Longitudinal section of a mature sporophyte containing the spore tetrads. H. Spore tetrad (the fourth spore cannot be seen in this plane). I. Mature spore. J to L. Germination of the spore and the formation of a gametophyte.** Courtesy of the Department of Botany, University of Delhi

part The canal of the neck contains a row of cells which disorganize when the archegonium is mature resulting in an opening of the neck (Fig 22 2 D).

The antherozoids liberated from the mature antheridia swim through the film of water which covers these plants as the result of dew or rain. They are perhaps attracted to the open necks of the archegonia by the extruded mass of disorganized canal cells Several antherozoids enter each archegonium but the one reaching first fertilizes the egg The fertilized egg is now the zygote You can perhaps now appreciate why bryophytes always grow in moist places They must have around them a film of water through which the motile male gametes may swim.

The zygote (a single cell to start with) divides repeatedly within the archegonium (Fig. 22.2 E and F). However, its product is not a thalloid *Riccia* but an entirely different body called the **sporophyte** or the spore producing generation A young sporophyte is called an **embryo.** The mature sporophyte of *Riccia* is just a spherical bag producing a large number of tiny unicellular spores (Fig 22.2 G to I). The sporophyte remains imbedded in the thallus, and the spores are liberated only after the death and decay of its wall and the thallus When favourable conditions are available, the spores germinate into small green filaments which subsequently grow into thalloid plants (Fig. 22.2 J to L) or **gametophytes** bearing the sex organs.

Thus the life cycle of *Riccia* is divisible into two distinct generations—the gametophytic and the sporophytic. The **gametophytic generation** comprises the green, free-living, independent thallus, the sex organs and the gametes. The **sporophytic generation** comprises the sac-like sporophyte. It is largely dependent on the gametophyte for shelter and nutrition.

There is thus a definite and regular alternation between the two generations. The gametes produced by the gametophyte fuse to form the zygote which now comes to have double the number of chromosomes and develops into the second generation or the sporophyte The cells of the sporophyte form the spore mother cells which undergo reduction division or meiosis to form the spores each of which has half the number of chromosomes The spores germinate to form haploid thalli Therefore, a spore is the first cell of a gametophyte, and a zygote the first cell of a sporophyte.

MOSS

Although a moss looks quite different from a liverwort it has the same type of life cycle. The plant is made up of a tiny stem with a number of small leaves borne spirally on it. The rhizoids arising from the base of the stem anchor the plant rather loosely in the soil. They also serve to absorb water and mineral salts However, the stem and leaves of a moss are not similar to the stem and leaves of higher plants because they do not have the vascular tissues in them and belong to the gametophytic generation. The sporophyte is borne on the gametophyte (Fig. 22.3).

Like the thalloid *Riccia*, the leafy plant of moss is a gametophyte (gamete producing plant). It bears clusters of antheridia and archegonia at the tips of the branches. Some species bear both antheridia and archegonia on the same plant (Fig 22 4 A); others have them on separate individuals The antheridia are club-shaped bodies borne on small stalks and usually have hair-like sterile filaments mixed with them (Fig. 22.4 B) The tip of the antheridium ruptures and the coiled biciliate antherozoids (male gametes) are liberated from them in large numbers (Fig. 22 4 C and D). They are dispersed over

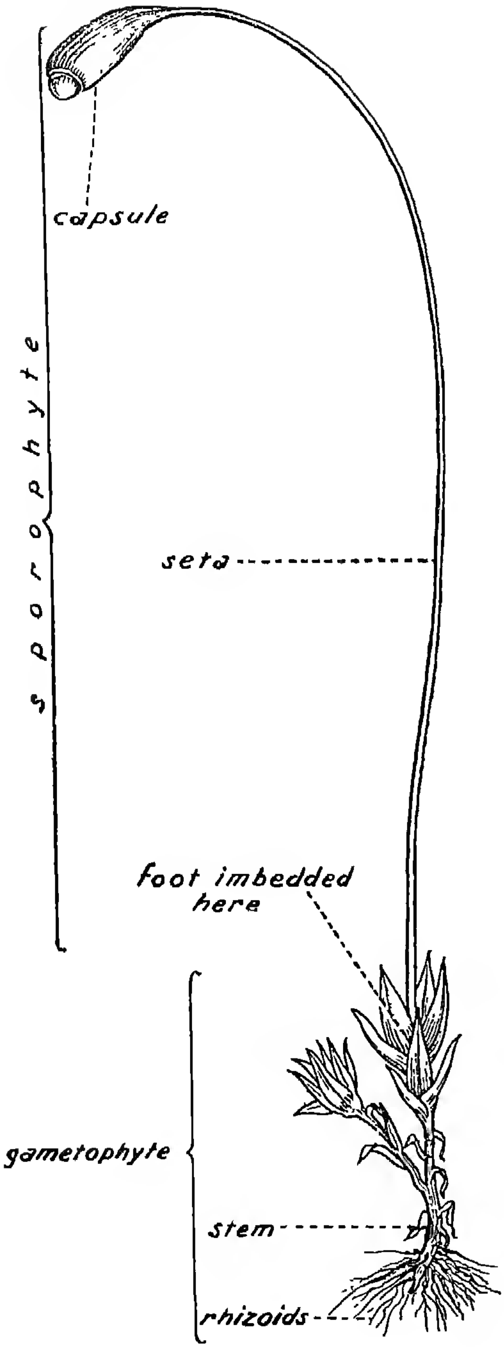

Fig. 22.3. A moss gametophyte bearing a mature sporophyte. Courtesy of the Department of Botany, University of Delhi.

the surface of the plant by rain drops or they swim through the film of water deposited on the plant as a result of dew. The archegonia (Fig. 22 4 E) are similar to those of *Riccia*. At maturity the neck of the archegonium opens (Fig. 22 4 F). Several antherozoids enter it and one of them fertilizes the egg. The zygote develops into the asexual generation or sporophyte (Fig. 22.4 G to J) It consists of three parts The lower conical region, called the foot, is imbedded in the apex of the gametophyte from where it absorbs food. The middle part or the seta usually stands above and out of the leafy shoot It carries on its top the spore case or **capsule** in which a large number of tiny spores are produced (Fig. 22.4 J to L) The capsule is covered by a delicate hood or **calyptra** derived from the upper part of the archegonium (Fig 22 4 J and K) The stalk conducts the food from the foot to the capsule When the spores are mature, the tip of the capsule falls off as a small cap. As the capsule sways to and fro due to wind, the spores are liberated into the atmosphere (Fig 22 4 M). In many mosses the mouth of the capsule is guarded by a ring of small teeth which allow the spores to escape only when the conditions for their dispersal are favourable The spores germinate to form a mass of green branched filaments which closely resemble a green alga (Fig. 22 4 N to P) Small buds eventually appear on the filaments and develop into leafy moss plants (Fig. 22.4 P). Thus there is a distinct and regular alternation of generations. The gametes produced by leafy plants fuse to form a zygote which develops into the sporophytic generation. This in turn produces asexual spores which give rise to the gametophyte.

Economic Importance

The bryophytes are of very little direct use. However, they play a useful role in

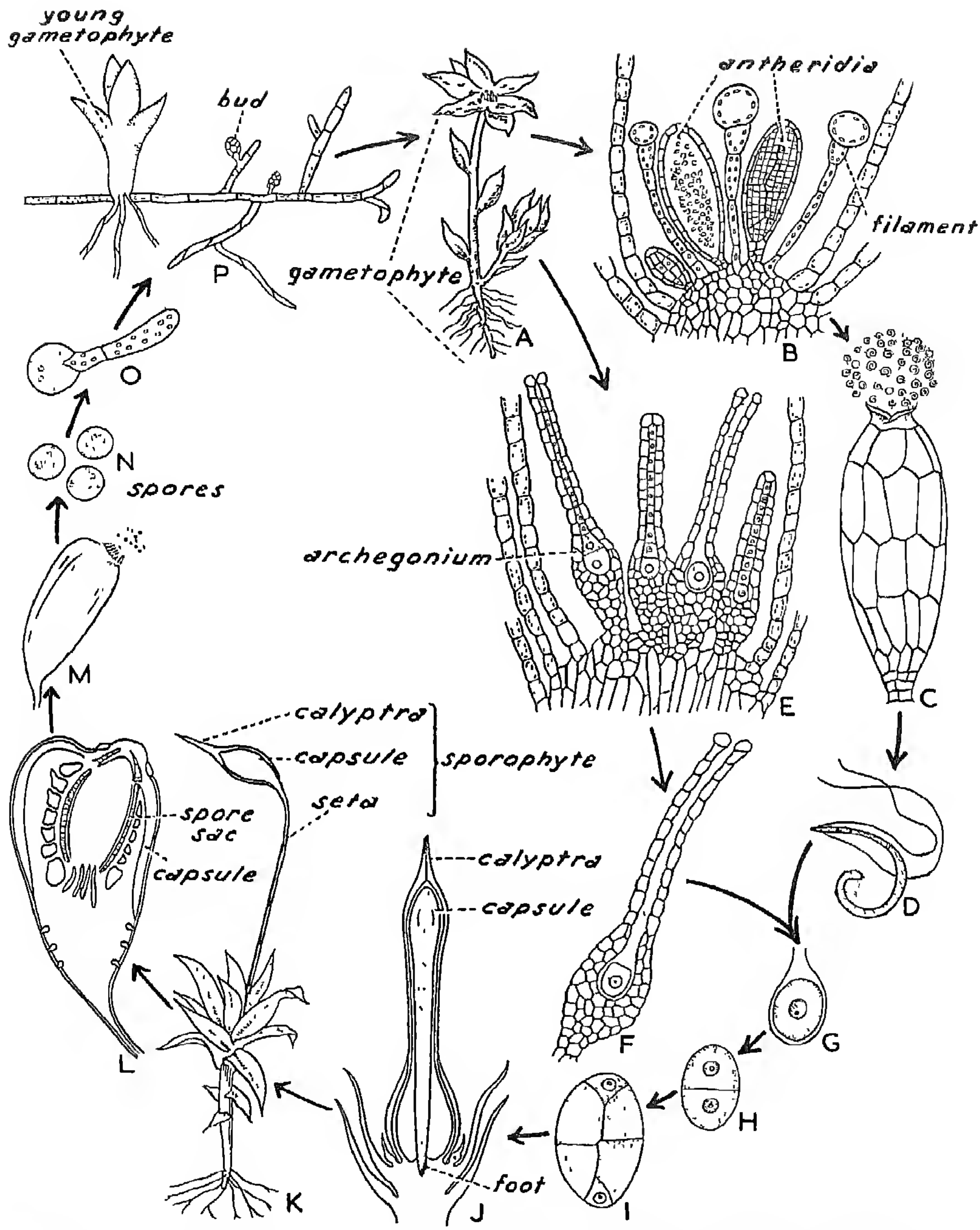

Fig. 22.4. The life cycle of a moss. A. Mature gametophyte bearing the male and female reproductive branches. B. Longitudinal section of male branch showing the club-shaped antheridia and green filaments. C. A mature antheridium that has ruptured at the tip liberating a mass of antherozoids. D. Antherozoid. E. Longitudinal section of a female branch showing a cluster of archegonia. F. The archegonium ready for fertilization. G, H and I. Early stages of development of the sporophyte. J. Longitudinal section of sporophyte still enclosed by calyptra Note the foot imbedded in the gametophytic tissue. K. The mature sporophyte borne on a gametophyte. L. Longitudinal section of capsule. M. Spores being dispersed from the capsule. N. Spores. O and P, Spore germination and the formation of a mass of alga-like filaments; the buds produced on such filaments develop into gametophytes. Courtesy of the Department of Botany, University of Delhi.

the economy of Nature. By their death and decay, they contribute to the organic matter in the soil which becomes more suitable for the growth of higher plants.

In a small way, the bryophytes also play some role in the prevention of **soil erosion.** Their extensive growth on the soil prevents it from being washed away.

Sphagnum, a moss found in swampy places, has remarkable absorptive and antiseptic properties. Hence it is sometimes used in surgical dressings In certain parts of England partly decayed plants of *Sphagnum* have formed the so-called peat This material is used as fuel.

SUMMARY

The bryophytes are small plants which lack roots, flowers and seeds. Many of them have small stems bearing tiny leaves. Others have thalloid bodies. They are, however, distinguished from thallophytes in producing embryos and in having their sex organs protected by a jacket of sterile cells The male sex organs are called antheridia, the female, archegonia.

The bryophytes include two main groups —liverworts and mosses. Their life cycle is divisible into two phases or generations—the gametophytic and sporophytic In *Riccia*, a representative liverwort, the gametophyte is a flat, green thallus that produces antheridia and archegonia. The antherozoids swim down the open neck of an archegonium and one of them fuses with the egg to form the zygote. The zygote develops into an embryo and then into a sac-like body or sporophyte which remains imbedded in the thallus. Eventually the sporophyte produces spores In this process the number of chromosomes is reduced to half The spores in turn germinate and produce the monoploid thallus. Thus, there is a regular alternation of the two generations The mosses have a similar life cycle but the moss sporophyte shows greater differentiation It has three parts—foot, seta and capsule.

The bryophytes are of no direct importance to human beings but play an indirect role in preventing erosion of the soil and in contributing to its organic content after their death and decay

QUESTIONS

1 Suggest an explanation for the fact that there are no trees among the mosses.
2. Why do bryophytes grow only where moisture is available for at least a part of the year?
3. Explain what you understand by alternation of generations. At what stage in the life cycle of *Riccia* is the number of chromosomes doubled? At what stage is it reduced to half?
4. Some people regard bryophytes as the

amphibians of the plant kingdom What is the justification for such a comparison?

5 Make a word-picture of the life cycle of a moss.

6 How will you distinguish a moss protonema from a green alga?

7 Write short notes on. calyptra, rhizoid, archegonium, vegetative reproduction in mosses

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CHAPTER 23

Pteridophyta

FERNS, club mosses and horse-tails, the three main groups of pteridophytes, resemble the spermatophytes in being differentiated into stems, leaves and roots containing xylem and phloem tissues. However, they differ from them in producing spores instead of seeds These plants were abundant in the remote past when they contributed to the formation of coal Ferns are by far the most abundant and familiar of all pteridophytes today.

The living club mosses or lycopods include *Lycopodium* and *Selaginella* They are small, dichotomously branched plants, rarely more than 0 5 metre high and bearing very small leaves The spores are produced in sporangia which are aggregated into small cones near the apices of the branches. These plants grow abundantly in mountainous parts of our country such as Darjeeling, Khasia Hills, Nilgiris, Kodaikanal and Ootacamund.

Species of *Equisetum* are also small plants rarely more than two metres in height. The plants have conspicuously jointed stems with alternating ridges and furrows and a whorl of small yellowish or brownish leaves at each node. The surface of the stem is very rough to touch due to the heavy deposition of silica in the epidermal cells The coarse stems are sometimes tied together in the form of small pads which are used for rubbing and cleaning kitchen utensils For that reason these plants are often called 'scouring rushes' Equisetums usually grow in moist, swampy regions and along the river banks.

Ferns are favourite garden plants A very curious form is the so-called walking fern. The tips of long spreading leaves strike roots when they touch the ground at some distance from the parent plant A new plant soon develops from each rooted leaf tip. The leaves of these new plants may repeat the process and a large area may soon be covered by this 'walking' process (Fig 23.1). Like the bryophytes, the pteridophytes also exhibit an alternation of generations The following account of the life cycle of a fern will bring out this point more clearly.

FERN

Dryopteris is a favourite fern grown in most gardens. It has a creeping, underground stem or rhizome. The young leaves are coiled like a watch spring but gradually assume a large pinnate form (Fig. 23.2) At certain points along its length the stem also bears tufts of slender roots which absorb water and mineral salts from the soil

The stem and root possess both parenchymatous and conducting tissues. The latter

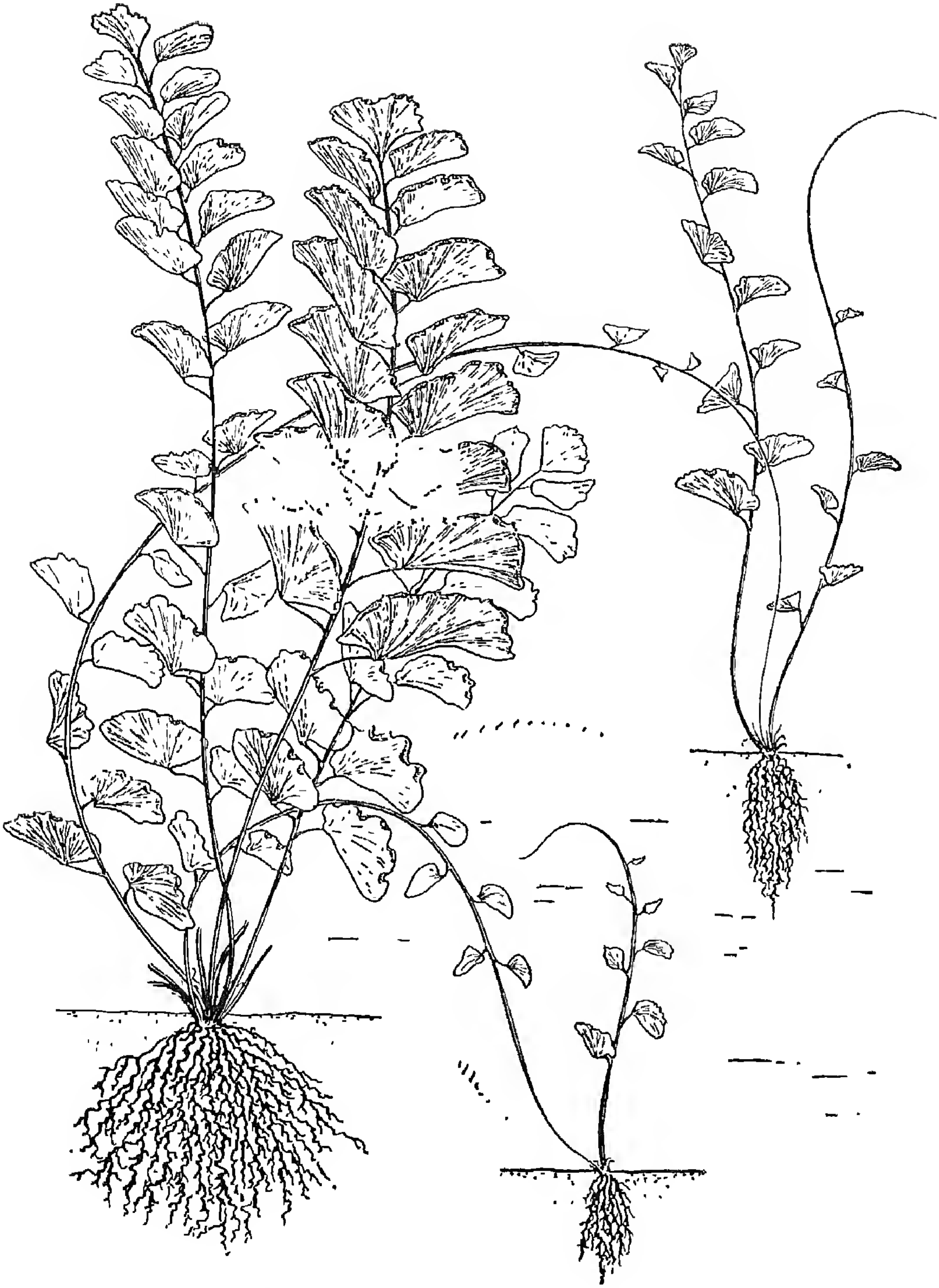

Fig. 23.1. **The 'walking fern' (*Adiantum*). Note the two young plants established from the tips of the leaves of the mother plant.** Courtesy of the Department of Botany, University of Delhi.

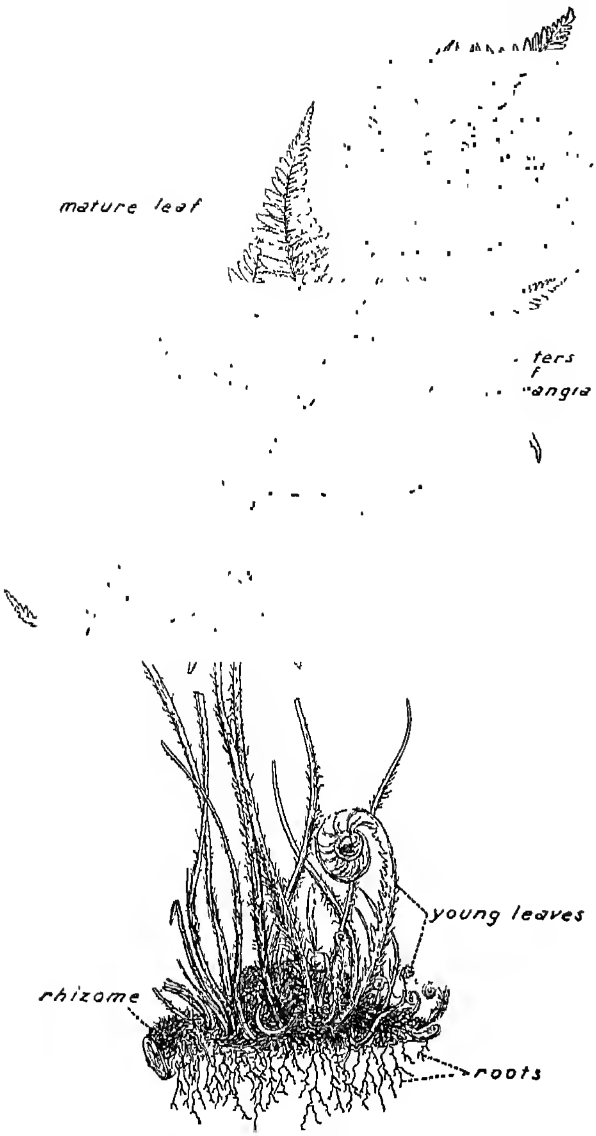

Fig. 23.2. A mature fern plant (*Dryopteris*). The young leaves are coiled like a watch spring. Courtesy of the Department of Botany, University of Delhi.

consist of xylem and phloem. During certain months of the year, depending upon the place, the leaflets bear small brownish areas on the lower surface near their margins. Each brown spot, when examined with a lens, reveals a cluster of globose, stalked structures called sporangia (Fig 23 3 A and B) The sporangial clusters are covered with membranous flaps Each sporangium contains numerous tiny spores (Fig. 23 3 C).

When the sporangium is ripe, its wall bursts and the spores are thrown out with force. You can observe this bursting by mounting a sporangium in a drop of glycerine on a glass slide (Fig 23 4)

The spores are light and easily carried about by wind On moist ground a spore may germinate to produce a tube-like green filament which soon grows into a flat, heart-shaped, thin and green structure with a conspicuous notch (Fig 23 5 A to C). This is the gametophyte of the fern plant It is fixed to the soil by means of hair-like rhizoids borne on its underside

On washing a gametophyte free of mud and examining its underside with a lens, you will find among the rhizoids the small, dome-shaped antheridia which produce a number of spirally coiled antherozoids bearing numerous cilia (Fig. 23.5 D and E) At maturity the antheridium bursts and the antherozoids escape. They swim about in the film of water that usually bathes the antheridia.

On the underside of the same gametophyte, near the notch, occur the archegonia. Their basal part is almost sunk in the gametophyte (Fig. 23.5 F) and contains the female gamete or egg. At maturity the tip of the neck opens and lets out a fluid The swimming antherozoids enter the neck and one of them fuses with the egg. The zygote

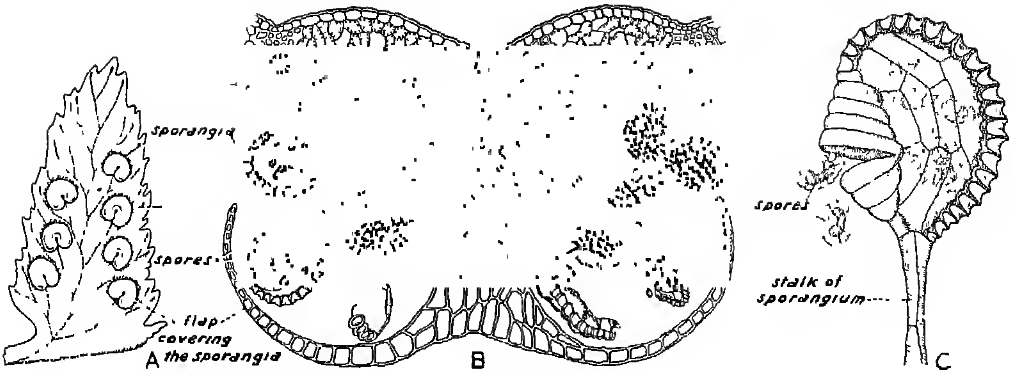

Fig. 23.3. Fern sporangium and spores. A. Part of a leaflet of *Dryopteris* enlarged to show the kidney-shaped sporangial clusters. B. Transverse section of a leaflet passing through the sporangial cluster. C. Sporangium and spores enlarged. A, from A.W. Haupt, *Plant Morphology*, McGraw-Hill Book Co , Inc , New York, 1933 B and C, from H.J Fuller and O Tippo, *College Botany*, Holt, Rinehart and Winston, New York, 1954

(Fig. 23.5 G) undergoes repeated divisions to form the embryo or young sporophyte (Fig. 23 6 A). This remains attached to the gametophyte, but soon strikes its own roots and becomes independent (Fig. 23 6 B). The gametophyte now withers away and dies.

It will be a fascinating experience to germinate fern spores on moist flower pots. This will enable you to see some stages in the development of the gametophytes.

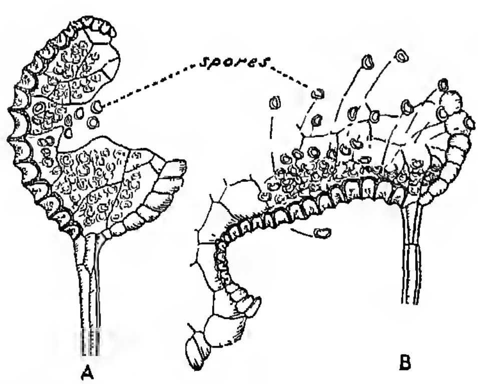

Fig. 23.4. Bursting of the wall of a fern sporangium to release the spores. A. Partly opened sporangium. B. Completely opened sporangium. After the spores are released, the wall once again snaps back into its original position. Courtesy of the Department of Botany, University of Delhi.

Alternation of Generations

As in the bryophytes, the pteridophytes also have two distinct phases or generations in their life cycle. The familiar plant which we know as a fern is the sporophyte. It produces spores in sporangia. The spores grow into the heart-shaped gametophytes which form the antherozoids and eggs (the male and female gametes respectively) When the gametes fuse, a zygote is formed This is the beginning of a new sporophyte which repeats the same story. Thus a sporophyte alternates with a gametophyte.

In pteridophytes the sporophyte is the more conspicuous (dominant) part of the life cycle. It is independent and free living except at a very young stage when it is still attached to the gametophyte. The latter is a short-

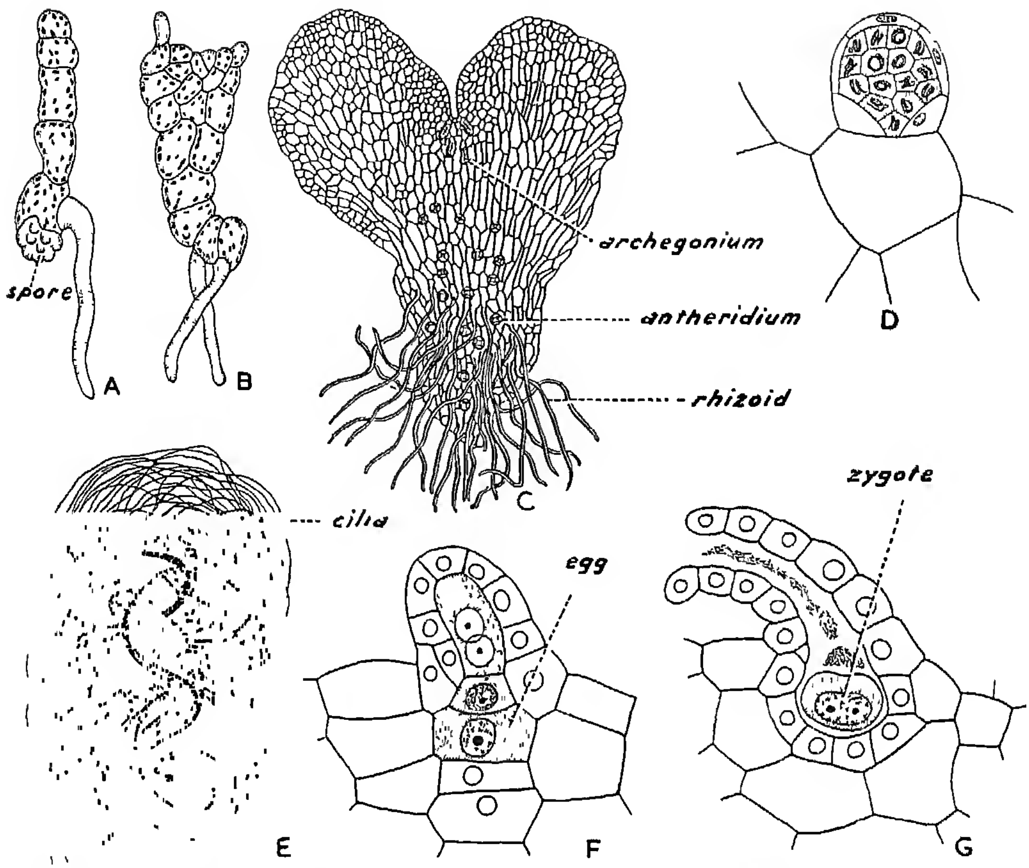

Fig. 23.5. The gametophyte of fern. A. Germinated spore. B. Young gametophyte. C. Mature heart-shaped gametophyte. D. Longitudinal section of an antheridium. E. An antherozoid showing the coiled body with numerous cilia. F. Longitudinal section of a mature archegonium. G. Longitudinal section of an archegonium in which the neck has opened and the egg has been fertilized. A and B, from H.J. Fuller and O Tippo, *College Botany*, Holt, Rinehart and Winston, New York, 1954. D to G, from A. W Haupt, *Plant Morphology*, McGraw-Hill Book Co., Inc , New York, 1953.

lived structure It disappears as soon as the sporophyte is well established.

You might recall that in *Riccia* it is the gametophyte that is free living and the more conspicuous phase of the life cycle while the sporophyte is merely a sac-like structure permanently attached to the gametophyte and dependent on it for food In pteridophytes the situation is reversed. The moss plant presents an intermediate situation.

The sporangia contain the spore mother cells which undergo reduction divisions so that each spore receives a monoploid nucleus. The spores start the gametophytic generation which is also monoploid. The gametes formed in the sex organs are consequently also monoploid When an antherozoid fuses with an egg their nuclei fuse with each other Thus the resulting zygote has the diploid number of chromosomes and is the beginning of the sporophytic generation.

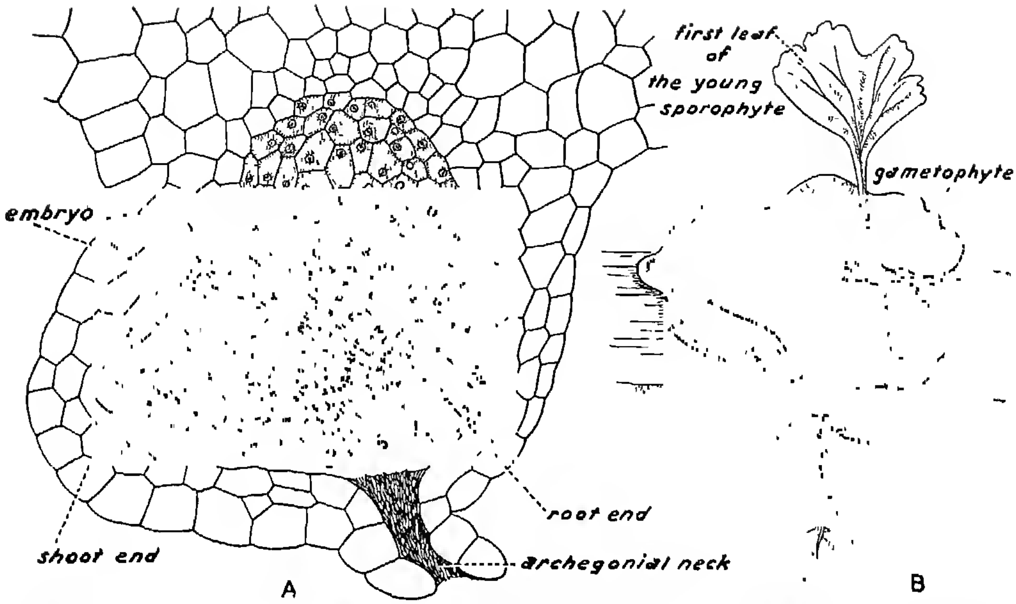

Fig. 23.6. Embryo and young sporophyte of a fern. A. Section of the gametophyte passing through an embryo; note the apical cells at the root and shoot ends. B. Young sporophyte still attached to gametophyte. A, from A W Haupt, *Plant Morphology*, McGraw-Hill Book Co., Inc, New York, 1953 B, from H J Fuller and O Tippo, *College Botany*, Holt, Rinehart and Winston, New York, 1954

Economic Importance

During very ancient times, millions of years ago, there existed extensive forests of various kinds of pteridophytes The environment of the earth then changed radically and these plants perished Their remains, together with those of other plants, became buried in the earth. By compression and other changes these were transformed into coal which is the chief source of fuel.

The ferns of today are useful mostly as ornamental plants They are widely grown in gardens, greenhouses and homes Their leaves are used in bouquets and floral arrangements The starchy rhizomes and young shoots of a few ferns are used as articles of food by villagers. A drug obtained from the rhizomes of the 'male fern' (*Dryopteris filix-mas*) has been used for hundreds of years as a cure for tapeworm

SUMMARY

Pteridophytes are plants that possess stems, leaves, and roots but no flowers or seeds. The most familiar types are the ferns, lycopods and equisetums The plant body contains both parenchymatous and vascular tissues. The lycopods include *Lycopodium*

and *Selaginella* These are small plants that are common on the mountains in our country. *Equisetum* has green, jointed stems with alternating, longitudinal ridges and furrows, and a whorl of very inconspicuous leaves at each node Ferns are favourite garden plants.

Like the bryophytes the pteridophytes too exhibit an alternation of generations In ferns, for instance, the plant we commonly see represents the sporophytic generation The sporangia occur on the under surface of the leaves and produce spores which germinate to give rise to the gametophytes. The gametophyte bears the antheridia and archegonia on its lower side. The antheridia liberate antherozoids which swim down the neck of the archegonium and bring about the fertilization of the egg The zygote gives rise to an embryo and then to a leafy sporophyte which is the more conspicuous part of the life cycle.

QUESTIONS

1. In a fern gametophyte the antheridia usually ripen much before the archegonia. What is the significance of this difference in the time of maturation?
2. Why are most ferns confined to fairly wet areas?
3. How can you distinguish the gametophyte of a fern from that of a liverwort?
4. In what sense are the pteridophytes more 'advanced' than the bryophytes?
5. List the similarities between the bryophytes and the pteridophytes.
6. In what ways do the sporophytic and gametophytic generations of the pteridophytes differ from those of the bryophytes?
7. Make an outline diagram of the life history of fern
8. On seeing the circular spots on the under side of the leaves of some potted ferns, a gardener began to think that the plants were 'diseased'. How will you rectify his misconception?

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